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Which Variables Influence Farmer Adoption of Genetically Modified Orphan Crops? Measuring Attitudes and Intentions to Adopt GM Matooke Banana in Uganda

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Which farmers are most likely to adopt genetically modified (GM) versions of African carbohydrate staples (also known as orphan crops)? This study investigates the variables that determine attitudes and intentions to adopt matooke banana in Uganda. Participatory ranking exercises undertaken with 167 randomly selected farmers and focus groups consisting of an additional 94 farmers suggest that attitudes and potential patterns of adoption will vary significantly according to region, farm size, membership in a farmer's association, previous experience with improved varieties and visits from extension workers. This research underscores the potential differentiated impacts of the commercialization of GM crops among African farmers.

Key words: Africa, farmer adoption genetic modification, matooke banana, orphan crops, Uganda.

Introduction

Enthusiasm is mounting over the possibility for genetically modified (GM) crops to help African farmers improve their yields and livelihoods. Over the past decade, a rash of public-private partnerships have emerged, facilitating license-free access for government researchers to produce GM varieties reflecting traits and varieties prioritized by smallholder producers (Dawson, Hedley, Guarino, & Jaenicke, 2009; Varshney et al., 2012). Current experiments are focused on GM versions of African carbohydrate staple crops such as cassava, sorghum, cowpea, millet, and banana; these are so-called 'orphan' crops because their lack of profit potential has left them virtually shut out of the genomic revolution that has vastly improved the fortunes of their commodity-crop counterparts.

Given this growing interest, there is surprisingly little empirical research investigating farmer attitudes toward these soon-to-be-commercialized GM varieties in Africa. What do African farmers think about these GM versions of their carbohydrate staples? Do they share the enthusiasm of proponents who herald GM as a technology that can help transform agricultural production on the continent? Are they concerned about potential health or environmental consequences? Will they adopt GM varieties of these orphan crops if and when they are commercialized?

A small but growing literature explores attitudes toward these soon-to-be-released varieties among consumers (Kimenju & De Groote, 2008; Kushwaha, Musa, Lowenberg-DeBoer, & Fulton, 2008), stakeholders (Aerni, 2005), gatekeepers (Bett, Okuro Ouma, & De Groote, 2010), and experts (Adenle, 2013). But the views of the farmers themselves—perhaps the most crucial group of intended beneficiaries—remain underexplored (though for exceptions see Edmeades & Smale, 2006; Kikulwe, Birol, Wesseler, & Falck-Zepeda, 2011a; Kikulwe, Wesseler, & Falck-Zepeda, 2011b; Lewis, Newell, Herron, & Nawabu, 2010). This study aims to increase our understanding of which socioeconomic variables influence farmer decision-making around GM carbohydrate staple crops in Africa by utilizing a methodological approach that incorporates both quantitative and qualitative methods. We focus on the case study of Uganda, a country that is emerging as a continental leader in GM agriculture.[1]

Timing is critical. There is a great need for diagnostic research that analyses attitudes toward new GM varieties before they are commercially released, as these are the major predictors for both adoption rates and use intensities (Adesina & Baidu-Forson, 1995; Cook & Fairweather, 2003; Edmeades & Smale, 2006; Hall, 2008; Smale & De Groote, 2003). Probing *ex-ante* attitudes is crucial to predicting how farmers will react to these technologies once they are released, as well as the extent to which they will transform agricultural production (Ho, Zhao, & Xue, 2009). Our aim is to uncover the potential stratified patterns of adoption that will emerge once these GM crops are commercialized in Uganda, by

1. *The Biotechnology and Biosafety Bill, introduced in the Ugandan Parliament in 2012, will allow for the commercialization of GM crops in the country. As of this writing, the bill has not been passed.*

identifying which socioeconomic factors play a part in shaping farmer attitudes.

GM Matooke Banana

Uganda's experimental program with agricultural biotechnology is now one the largest in Africa, buoyed by significant investments in infrastructure, experimental capacity, and personnel training in the last decade, largely sourced from the United States Agency for International Development and the Bill and Melinda Gates Foundation (Schnurr, 2013). The widespread adoption of GM crops is a key element of the government's strategic commitment to expanding the use of agricultural technology throughout the country (Ministry of Finance and Planning and Economic Development, 2010).

The hallmarks of Uganda's experimental program are GM versions of the East African Highland Banana, known locally as matooke—the country's primary carbohydrate staple. Unlike the Cavendish bananas familiar to most North Americans and Europeans, matooke bananas are eaten before they are ripe; generally they are peeled, boiled, and then roasted over a fire to produce a thick mash. Matooke provides an estimated 30% of Uganda's daily caloric intake and occupies the greatest proportion (38%) of utilized agricultural land across the country (Kalyebara, Wood, & Abodi, 2007). Ugandans consume more bananas per capita—more than a half-kilogram of banana per day per person—than anyone else on the planet (Interview with Research Scientist #1, May 27, 2009).

A range of experimental trials are currently underway investigating matooke that is genetically modified to resist some of the region's most pernicious pests and diseases, including banana bacterial wilt, fusarium wilt, black sigatoka fungus, nematodes, and weevils, as well as GM versions that are biofortified with Vitamin A to help reduce rates of maternal and infant mortality. Multi-stage confined field trials are ongoing. The senior research scientists in charge of the National Agricultural Research Organisation's banana experimental program predicts that GM matooke could be ready for commercialization as soon as 2018 (Interview with Research Scientist #2, May 18, 2014).

Methods

Sampling

Our starting point was the 2008/09 Uganda Census of Agriculture, which reported that 98.6% of all matooke bananas produced in the country were located in three major growing regions—eastern, central, and southwestern. These also represent three distinct agroecological zones: the eastern and central are in the lowlands where pests and diseases are rife, while the southwestern is located in the highlands with a relatively low incidence of pests and diseases. The country's matooke farmers are split unevenly between the three growing regions, with 15% of all matooke farmers located in the east, 35% are located in the central region, and 50% are located in the southwest. We set out to create a stratified random sample to generate a dataset that reflected this geographical distribution. Random sampling ensures that everyone has an equal chance of being selected for the study, and thus is the most effective sampling strategy for identifying potentially relevant variables that influence attitudes and adoption rates. Districts were randomly selected based on an updated list provided by the most recent census. A random number generator was then used to select sub-counties, parishes, villages, and individual households.[2]

Participants

A power analysis was conducted for the most complex analysis in this article using a Kruskal-Wallis test with three groups. Assuming a medium effect size (partial $\eta^2=0.09$), an alpha of 0.05, and three groups, we would require 132 participants to achieve 90% power. In order to account for attrition and missing data, we recruited 167 farmers for the quantitative section of this study—33 from the eastern region, 63 from the central region, and 71 from the western region (see Figure 1). Ninety-seven farmers were female and 70 were male. More than 85% of these farmers had not completed formal schooling beyond secondary. Participants were mostly smallholders; the average farm size was 6.48 acres (SD=12.78), with 54% of farmers having fewer than three acres. Farmers were generally quite poor, with average expenditures per week of USD $15.80 (SD=$23.10) and an average of eight dependents per household (SD=4.90).

Protocols

This research combines qualitative and quantitative methodologies to catalog the multiplicity of factors that influence farmer attitudes and intentions to adopt to GM crops. It bridges the gap between the models and sur-

2. *Certain districts and sub-counties were excluded based on health and safety concerns, as well as inaccessibility due to the rainy season.*

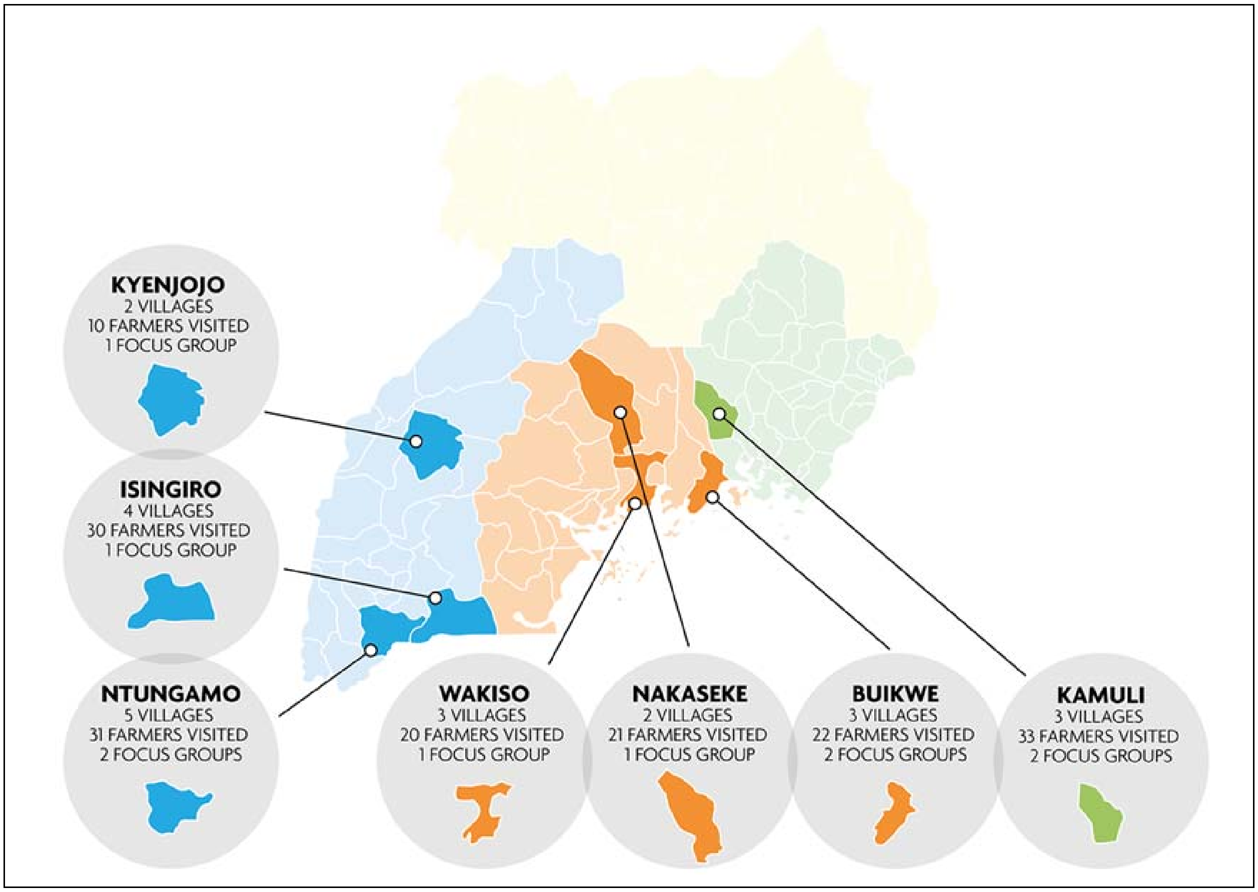

Figure 1. Sampling map.

veys (favored by economists and the ethnographies) and participant observation (favored by anthropologists) to offer an innovative methodological approach for evaluating farmer attitudes and behavioral intentions to adopt new GM varieties of African staple crops. We adhered to a model of sequential explanatory design (Ivankova, Creswell, & Stick, 2006), whereby the quantitative and qualitative data were collected in two discrete phases.

Quantitative Methods

Each farmer was asked to participate in an hour-long on-farm session that included survey questions and participatory ranking exercises. The quantitative methods utilized in this project emerged out of the theoretical framework of participatory plant breeding, which seeks to integrate farmers into the agricultural innovation process (Bellon & Reeves, 2002; Ceccarelli & Grando, 2007; Thompson & Scoones, 2009). It consists of a progression of exercises that relies heavily on visual aids and side-by-side comparisons designed to bridge the gap between hypothetical exercises and farm-level realities. All quantitative methods were conducted on-farm between May 2012 and October 2013. These protocols were facilitated by the Ugandan project co-ordinator, who has over two decades of experience in working agricultural development and consulting. All of the materials were translated into the local language (Lugandan, Lusoga, Ruyankore, or Rutooro). Each on-farm session consisted of three components, adapted from Soleri et al. (2005, 2008).

Attitudinal Statements

Each farmer was read a series of 11 attitudinal statements (listed in Appendix A) about the potential benefits and limitations of GM matooke banana and then asked to report the degree to which they agree or disagree with the statement, using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree; questions were based on those used by Kikulwe et al., 2011a, 2011b). In our analysis, we combined the statements into a single combined attitudinal variable by averaging all items together. This combined variable has

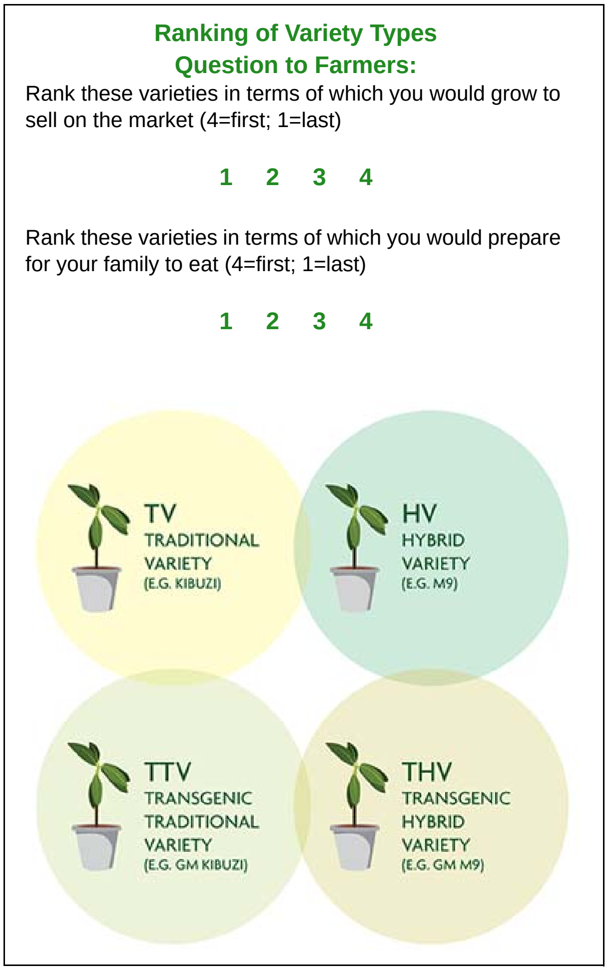

Figure 2. Graphic of ranking of variety types exercise.

good internal consistency (α=0.87), supporting the choice to combine the statements.

Ranking of Varietal Types

Four types of planting materials (represented by banana suckers) were physically placed in front of the farmer—a traditional farmer variety (FV), a modern variety improved through conventional breeding techniques (MV), and transgenic versions of these same varieties (TFV and TMV; see Figure 2). Farmers were then asked to rank these four varieties in terms of what they would sow a) for the market and b) for household consumption. To facilitate analysis, we combined the six ranking exercises into four composite variables by averaging items across each of the four varieties—prefers farmer variety (α=0.87), prefers modern variety (α=0.94), prefers GM farmer variety (α=0.96), or prefers GM modern variety (α=0.84). Each composite variable had good internal consistency, supporting this choice.

Future Scenarios

Each farmer was presented with four future scenarios depicting the benefits and risks associated with GM technology and asked for his or her response to each scenario (good, bad, does not matter, depends on the consequences). Future scenarios are stories that simplify complex realities into terms that are comprehensible to semi- or illiterate farmers, while still maintaining biological accuracy. Previous research has used scenarios to empirically assess farmer attitudes towards GM technology prior to its commercial release (Chong, 2005; Kikulwe, 2010). The scenarios for the current study were constructed based on templates used in prior research (Soleri et al., 2005, p. 160), and adapted to reflect the particularities of the Ugandan case study. The scenarios were presented to plant breeders, policy experts, and civil society organizations and endorsed by all stakeholders as accurate and neutral representations of GM technology. The four scenarios were a) 'what do you think of this act of putting properties of maize, rice, and sweet peppers into matooke?'; b) 'are you concerned about environmental consequences?'; c) 'are you concerned about health consequences?'; and d) 'do you have confidence that governmental institutions can protect you against possible risks associated with this technology?'.[3]

Qualitative Methods

Selected farmers were then invited to a day-long focus group that took place in the months after the on-farm visit. Farmers were recruited with the aim of maximizing diversity in terms of age, gender, land size, and wealth. Focus groups consisting of 6-10 farmers were convened in each of the selected districts to provide insight into the meaning of quantitative results (Weinhold, Killick, & Eustáquio, 2013). Each focus group began by undertaking the same series of exercises described above as a collective, prompting members to

3. *Each future scenario presented respondents with three possible answers—'no,' 'depends on the consequences,' and 'yes'. For each scenario, some expected cell counts for these answers were below 5, which violates one of the assumptions of chi-square analysis. For each scenario, we therefore combined the 'no' and 'depends on the consequences' responses into one category so that the expected cell counts would exceed 5.*

question, listen, and disagree as they tried to achieve consensus. Focus groups were separated by gender to allow women and men a space to express shared ideas, voices, and silences (Hopkins, 2007; Pini, 2002; Pratt, 2002). During focus groups, farmers were asked to explain their reasons for their response to these activities. Additionally, farmers were asked to describe gender differences, marketing constraints, and labor practices associated with matooke farming. The ensuing discussion provided deeper insight into farmers' decision-making process and their perceptions towards GM, which serves as an important complement to the quantitative data collected.

Data Analytic Strategy

Eleven independent variables (region, farm size, membership in a farming association, experience with improved varieties, previous visits from extension officers, gender, age, wealth, education level, number of dependents, and years spent farming) were tested as predictors of farmer uptake of GM technology as expressed by the attitudinal statements, ranking of varietal types, and responses to future scenarios. All independent variables were based on the self-reported data provided by participants during the on-farm interviews. Results were found for region, farm size, membership in a farming association, experience with improved varieties, and previous visits from extension officers. All are discussed below. Distributional qualities of variables were assessed using histograms, normal P-P plots, skewness and kurtosis values, and Levene's test for homogeneity of variance. Many variables were non-normally distributed and violated the assumptions of parametric tests. Thus, we opted for non-parametric tests or robust alternatives for hypothesis testing throughout the results (for example, Mann-Whitney U tests, Kruskal-Wallis tests, Spearman correlations, chi-squares, and logistic regression).

An inductive content analysis was undertaken for the focus-group data. This involved a systematic and methodical examination of all transcripts to identify key words, sections, and sentiments, leading to a further classification of major themes and concepts. This qualitative analysis was further bolstered by implementing quality measures such as feedback sessions with farmers, allowing them an opportunity to expand on or correct previous communications, as well as triangulation via a comparison of focus-group data alongside quantitative data and field notes.

Results and Discussion

Region

Kruskal-Wallis tests were used to examine the effect of region on the combined attitudinal variables and combined rankings of varietal types. The Kruskal-Wallis test is a nonparametric test used to compare three or more samples, and is robust to violations of the normality assumption. As can be seen from scores on the combined attitudinal variable in Table 1, the central region is significantly more likely to have a negative perspective of GM—$H(2)=47.923$, $p<0.001$ as compared to the eastern ($p<0.001$) and southwestern ($p<0.001$) regions. For the ranking of variety types, the eastern region is significantly more likely to rank the farmer variety lower, $H(2)=23.31$, $p<0.001$, than both the central ($p<0.001$) and southwestern ($p<0.001$) region. Region did not affect responses to the modern variety and transgenic farmer variety ranking. For the transgenic modern variety ranking, the eastern region is significantly more likely to rank this variety higher, $H(2)=27.85$, $p<0.001$, than the southwestern ($p<0.001$) and central ($p<0.001$) regions (ps<0.001). Overall, these results suggest that farmers in the eastern and southwestern region hold more positive attitudes towards GM matooke than do farmers in the central region, with farmers in the east showing the most interest in GM varieties.

Pearson chi-square tests were used to measure the influence of region on farmer reactions to the future scenarios. For Future Scenario A ('What do you think of this act of putting properties of maize, rice, and sweet peppers into matooke?'), region significantly predicted responses, χ^2 $(N=164)=19.60$, $p<0.001$. The southwestern region (85.7%=good) had the most positive attitudes, followed by the eastern region (74.2%=good) and finally by the central region (50.8%=good). For Future Scenario B ('Are you concerned about environmental consequences?'), region significantly predicted responses, χ^2 $(N=165)=14.23$, $p=0.001$. The eastern region (100% yes) was the most concerned, followed by the central region (77.4%=yes) and the southwestern (66.2%=yes). For Future Scenario C ('Are you concerned about health consequences?'), region significantly predicted responses, χ^2 $(N=165)=15.03$, $p=0.001$. The eastern region (93.8%=yes) was the most concerned, followed by the central (85.2%=yes) and southwestern (63.4%=yes) regions. For Future Scenario D ('Do you have confidence that governmental institutions can protect you against possible risks associated with this new technology?'), region again significantly pre-

Table 1. Region and combined variables.

Variables	Region	N	Mean	Std. deviation	Kruskal-Wallis test statistic (H)
Pro GM attitude	Central	60	2.92^a	0.80	47.92***
	Eastern	33	3.95^b	0.62	
	Southwestern	71	3.89^b	0.78	
Prefers farmer variety	Central	60	1.92^b	0.71	23.31***
	Eastern	33	1.33^a	0.43	
	Southwestern	71	1.93^b	0.70	
Prefers modern variety	Central	60	1.88^b	0.60	2.50
	Eastern	33	2.03^b	0.57	
	Southwestern	71	2.39^b	1.26	
Prefers GM farmer variety	Central	60	3.26^b	0.50	3.97
	Eastern	33	3.06^b	0.45	
	Southwestern	71	2.70^b	1.23	
Prefers GM modern variety	Central	60	2.94^b	0.60	27.85***
	Eastern	33	3.60^a	0.51	
	Southwestern	71	2.98^b	0.63	

*Note: 'Pro GM attitude' represents farmers' combined scores to the 11 attitudinal statements that measured the extent of agreement with GM technology. 'Prefers farmer variety' represents the relative ranking farmers gave to an indigenous matooke variety. 'Prefers modern variety' refers to the relative ranking farmers gave a conventional or non-GM hybrid matooke variety. 'Prefers GM farmer variety' refers to the relative ranking farmers gave to a GM matooke when a Ugandan indigenous variety acts as the host. 'Prefers GM modern variety' refers to the relative ranking farmers gave to GM matooke when a conventional variety acts as the host. Superscript letters (a, b) are used to denote pairwise comparisons. Means that share a subscript within any given variable are not significantly different. Means that have differing subscripts are significantly different from each other at p < 0.05, after using a Bonferroni correction for multiple tests. *p < 0.05, **p < 0.01, ***p < 0.001.*

dicted responses to this question, χ^2 (N=164)=21.25, p<0.001. The eastern region (90.6%=yes) was the most confident, followed by the southwestern (74.3%=yes) and central (46.8%=yes) regions. These results corroborate a greater reticence towards GM crops within the central region relative to both the southwest and the east.

We hypothesize that a mix of historical and geographical factors contributes to these contrasting regional perspectives. First, the central region is the historic and cultural heartland of matooke. The crop has been systematically cultivated within the Buganda kingdom since the 15th and 16th centuries (Schoenbrun, 1993). Historically, the crop has served as an important component of engagement, marriage, and other religious ceremonies (Stephens, 2013). The cultural importance of matooke persists today; it is grown primarily for household consumption across the central region and plays an important role in many cultural activities. By comparison, matooke has less cultural and historical significance in the east and southwest. The crop was introduced in these areas in the late 19th and early 20th centuries by returning migrant laborers who worked seasonally on matooke plantations in the central region.

One farmer in the central region conveys this sense of hesitation around the potential of genetically modifying such an important cultural crop:

> Since I was born, I farmed matooke. Were they as God made them or were they mixtures? We are also questioning ourselves. Today we observe changes in soil characteristics, why? And we are wondering how it will be in future with the changes we are making (Buikwe District).

Another farmer expresses similar concern: 'Matooke is food for a true [Ugandan]. If this is not my staple, I am less concerned. But when it comes to bananas, that is my life' (Kamuli District).

In the southwest, matooke is grown primarily for commercial purposes. A Pearson chi-square test used to test whether region influences marketization patterns underscores how much of the matooke in this region is produced for market relative to the other regions. All farmers were asked whether they sell matooke that they grow, and region significantly affected their responses, χ^2 (N=167)=27.24, p<0.001. Farmers in the southwest are most likely to sell matooke (84.5%=yes), followed by the eastern (45.5%=yes) and central (44.4%=yes) regions. The increased marketization prevalent throughout the southwest appears to be one factor driving positive attitudes towards GM varieties. Farmers there were nearly unanimous in emphasizing the increased profits associated with a GM version resistant to pests and disease as the main driver behind their support: 'As a trader, I support high-yielding varieties because I look at the stool in terms of money. So the higher the growth rate, the higher the income for me' (Kyenjojo District). When asked about the greater reluctance towards GM in the other growing regions, many of the market-oriented farmers in the southwest appeared frustrated and impatient: 'those [in the other growing regions] don't know the problems we are facing. They just eat our food' (Isingiro District).

Our results regarding geographical location are also significant for debates around how attitudes towards GM vary among rural versus urban growers. Our findings suggest that the more highly urbanized central region seems less willing to accept GM matooke than the more rural southwest and eastern regions, which echoes other studies indicating that urban populations are more concerned about potential health and environmental consequences associated with GM crops (Kimenju & De Groote, 2008; Loureiro & Bugbee, 2005). The work of Kikulwe et al. (2011a, 2011b) in Uganda is particularly instructive here. In the first study, Kikulwe et al. (2011a) found that people living in and around urban areas—which describes many inhabitants of the central region—were less likely to support the introduction of a disease-resistant GM banana than those living in more rural areas. The study concluded that because rural inhabitants are poorer and also more frequently grow bananas, they are more likely to experience welfare gains associated with GM technology. In contrast urban consumers, who are generally wealthier and have more education, are likely to experience welfare losses given their concerns about potential health and food safety consequences. In another study investigating perceptions toward a GM banana with improved nutritional qualities, Kikulwe et al. (2011b) found that urban consumers were less willing to pay more for the GM version than rural consumers.

While on the surface our findings seem to support this portrayal of greater reluctance among urban residents, careful examination reveals nuances that complicate what we consider to be an overly simplistic portrayal of the urban/rural divide. For example, data from the ranking of varietal types (Table 1) suggest that if GM is based on farmer varieties, the central region actually shows more interest in the technology than the other two regions, while data from the future scenarios (presented below) underscore the highly differentiated perspectives among rural residents, especially with respect to farm size. These findings shed doubt on the utility and accuracy of the representation of a strict rural/urban divide in the Ugandan context, particularly with respect to matooke, which is a crop that is omnipresent throughout the country. Indeed, nearly every resident of the capital—including lawyers, scientists, journalists, professors, and President Yoweri Museveni himself—farm banana somewhere in the country. In sum, we are reluctant to overestimate the degree to which farmers' 'urban-ness' shapes their attitudes to GM matooke.

A final explanation for these regional variations in attitudes might be the uneven impact of the increasingly vocal opposition movement to GM crops. Robert Paarlberg (2008) has made this point most emphatically: more negative attitudes among urban residents in African cities are due to the influence of global campaigns designed to tarnish the image of GM as a technology that can improve yields and livelihoods in Africa, while others have provided more nuanced analysis of how access to information can shape attitudes (Adenle, Morris, & Parayil, 2013). Our findings lend some credence to Paarlberg's concern: the central region is the 'center of information,' as one activist campaigning against GM put it (Civil Society Member #1, November 30, 2013). This region is the most exposed to the message of oppositional non-governmental organizations (NGOs) because more people are literate, are more likely to read English newspapers and other print media, and are closer to radio stations in Kampala, where critical perspectives on GM are often expressed. Plus, Kampala is home to virtually all the civil society organizations expressing concern about the country's current push towards GM. The uneven impact of the anti-GM campaign might further explain the increased enthusiasm for these technologies in the eastern region. The same activist quoted above reported that, after the central region, NGO activity and mobilization against the Biotechnology and Biosafety Bill—which is currently before Parliament—has been more prevalent in the southwest than the east (Civil Society Member #1, November 30, 2013). The absence of NGO activities in the east may partly account for this region's greater willingness to plant transgenic varieties.

Table 2. Correlation matrix for age, land size, wealth, and combined variables.

Variables	1	2
1. Size of farm	1	0.22**
2. Average expenditure per week	0.22**	1
3. Pro GM attitude	0.33**	0.06
4. Prefers farmer variety	-0.14*	0.08
5. Prefers modern variety	-0.08	-0.03
6. Prefers GM farmer variety	0.13*	-0.04
7. Prefers GM modern variety	0.12	-0.04

Note: 'Pro GM attitude' represents farmers' combined scores to the 11 attitudinal statements that measured the extent of agreement with GM technology. 'Farmer variety' represents the relative ranking farmers gave to an indigenous matooke variety. 'Modern variety' refers to the relative ranking farmers gave a conventional or non-GM hybrid matooke variety. 'GM farmer variety' refers to the relative ranking farmers gave to a GM matooke when a Ugandan indigenous variety acts as the host. 'GM modern variety' refers to the relative ranking farmers gave to GM matooke when a conventional variety acts as the host.

$**p < 0.01$ (1-tailed). $*p < 0.05$ (1-tailed).

Listwise N = 162.

Farm Size

Spearman rank-order correlations (r_s)—a non-parametric alternative for a Pearson correlation (r)—was used to test whether farm size was significantly correlated with perceptions toward GM technology. Table 2 shows that farm size has a significant positive correlation with the combined attitudinal variable, with a medium effect size. r_s=0.33, p<0.001 (significant at the two-tailed level). This means that the larger the farm, the more likely respondents are to hold positive attitudes towards GM crops. Farm size is also negatively correlated with preferences for the conventional variety rankings, r_s=-0.14, p=0.040, and positively correlated with preferences for the transgenic variety rankings, with small effect sizes for both. So, as farm size increases, preference for conventional varieties decreases and preference for transgenic varieties increases, r_s=0.13, p=0.049 (both correlations are significant at the one-tail level).

We also tested farm size to choices on future scenarios A, B, C, and D using logistic regression. As can be seen from Table 3, all tests were non-significant (ps>0.05). Thus, while the combined attitudinal and ranking variables suggest that farm size influences positive attitudes towards GM, this result does not hold for the future scenarios. In part, this discrepancy may reflect the fact that the future scenarios provided only two possible answers for respondents, generating less variance within these data as compared to the other variables.

Table 3. Logistic regression on farm size and the future scenario variables.

Variable	B (SE)	Odds ratio	95% CI odds ratio	Pseudo R^2
Future scenario A				
Intercept	0.70 (0.20)**			
Farm size	0.03 (0.02)	1.03	[0.98, 1.08]	0.02
Future scenario B				
Intercept	1.29 (0.21)***			
Farm size	-0.01 (0.01)	0.97	[0.97, 1.01]	0.01
Future scenario C				
Intercept	1.32 (0.21)***			
Farm size	-.001 (0.01)	0.99	[0.96, 1.01]	0.01
Future scenario D				
Intercept	0.65 (0.19)**			
Farm size	0.01 (0.01)	1.01	[0.98, 1.04]	0.00

Note: The pseudo R^2 is the Nagelkerke R^2. $*p < 0.05$, $**p < 0.01$, $***p < 0.001$.

Our findings regarding farm size diverge from previous research investigating perceptions of GM crops in East Africa. Edmeades and Smale (2006) suggest that poorer households are more likely to be interested in purchasing GM planting materials than wealthier ones, while Kikulwe et al. (2011a) conclude that poor farmers will benefit most from GM matooke. In our study, wealth (measured as average expenditure per week) does not influence willingness to adopt. Yet farm size, which does significantly correlate with perceptions towards GM crops (see Table 2), can also serve as a proxy measurement for wealth. These findings support the view that wealthier farmers are more likely to adopt GM crops than poorer ones.

This finding regarding farm size—and by extension, wealth—likely reflects the possibility that larger farmers are more market-oriented than their smaller counterparts, producing the bulk of their matooke for sale rather than home consumption. Larger farmers tend to be more integrated into marketing systems, and thus may be more confident that they can sell increased yields of matooke. A Mann-Whitney U test was used to measure the influence of land size on responses to the question 'do you sell matooke that you grow?' Farm size signifi-

Table 4. Membership in farmers' organization and combined variables.

	Member in an organization	N	Mean	Std. deviation	Mann Whitney test statistic (U)
Pro GM attitude	Yes	79	3.67	0.88	2816.50
	No	83	3.46	0.88	
Prefers farmer variety	Yes	80	1.67	0.57	4024.50*
	No	85	1.95	0.79	
Prefers modern variety	Yes	80	1.84	0.69	4399.50**
	No	85	2.41	1.07	
Prefers GM farmer variety	Yes	80	3.27	0.67	2271.00***
	No	85	2.69	1.02	
Prefers GM modern variety	Yes	80	3.23	0.54	2621.00*
	No	85	2.96	0.71	

Note: 'Pro GM attitude' represents farmers' combined scores to the 11 attitudinal statements that measured the extent of agreement with GM technology. 'Farmer variety' represents the relative ranking farmers gave to an indigenous matooke variety. 'Modern variety' refers to the relative ranking farmers gave a conventional or non-GM hybrid matooke variety. 'GM farmer variety' refers to the relative ranking farmers gave to a GM matooke when a Ugandan indigenous variety acts as the host. 'GM modern variety' refers to the relative ranking farmers gave to GM matooke when a conventional variety acts as the host.

$^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

cantly altered responses to this question, U=1751, p<0.001. Farmers who responded 'yes' owned on average 7.78 hectares, whereas those who responded 'no' owned on average 4.40 hectares. One farmer from the southwest argued that larger farmers were more forward thinking than their smaller counterparts: 'Small-scale farmers refuse the change because they only produce for themselves. But large-scale farmers target markets' (Isingiro District). Another farmer from the southwest expressed confidence in GM as a tool to increase yield, which would allow him to meet increased demand: 'There is a market always, and more people are starting to eat banana, including people from northern Uganda' (Ntungamo District).

The fact that smallholders express less enthusiasm for GM matooke casts doubt on claims that these technologies will be able to help the poorest and most vulnerable farmers. Smaller-scale farmers expressed concern about their capacity to buy replacement planting materials over time ('we have small plots of land. So replacing would be expensive and require more land than I have' [Buikwe District]), while another felt that the larger yields due to pest and disease resistance would necessitate more land than he had available ('you need a big plot of land to grow [GM varieties]' [Buike District]). Others preferred the traditional varieties that they've grown up with: 'we are living on a plot 50 × 100 feet. I would prefer [traditional varieties] and continuously care for it' (Wakiso District). The implication of these findings is that GM matooke might be favored by larger, wealthier farmers more than smaller, poorer farmers. These results resonate with studies conducted elsewhere that similarly found that larger, more affluent farmers are better positioned and more willing to take on the risks associated with the adoption and implementation of new, improved varieties (Arechavala-Vargas, Díaz-Pérez, & Huerta-Ruvalcaba, 2007; Consmuller, Beckmann, & Petrick, 2010; Skevas, Kikulwe, Papadopoulou, Skevas, & Wesseler, 2012).

Membership in a Farmers' Organization

A Mann-Whitney test was used to examine the effect of membership in a farmers' organization on the combined attitudinal variable and the combined ranking variables. As Table 4 reveals, membership in a farmers' organization does not significantly influence farmer responses to the combined attitudinal variable (U=2816.5, p=0.121), but it does significantly affect their ranking of transgenic versus non-transgenic matooke varieties. Farmers without membership in an organization have a more positive view towards non-GM farmer varieties than members (U=4024.5, p=0.04). Farmers without membership in an organization also have a more positive view towards non-GM modern varieties than members (U=4399.5, p=0.001). Correspondingly, farmers who belong to an organization have a more positive view of GM farmer varieties (U=2271, p=0.000) and GM modern varieties (U=2621, p=0.011).

We also used a Pearson chi-square test to measure the influence of membership in a farmers' organization on responses to the future scenarios. There were no significant results for Future Scenario A (p=0.060), B

Table 5. Previous experience with improved varieties and combined variables.

	Previous Kawanda experience	N	Mean	Std. deviation	Mann Whitney test statistic (U)
Pro GM attitude	Yes	63	3.75	0.77	2320*
	No	93	3.39	0.97	
Prefers farmer variety	Yes	64	1.61	0.59	3793**
	No	94	1.99	0.78	
Prefers modern variety	Yes	64	1.80	0.57	3893**
	No	94	2.38	1.10	
Prefers GM farmer variety	Yes	64	3.34	0.55	1924***
	No	94	2.70	1.03	
Prefers GM modern variety	Yes	64	3.24	0.60	2173**
	No	94	2.94	0.68	

Note: 'Pro GM attitude' represents farmers' combined scores to the 11 attitudinal statements that measured the extent of agreement with GM technology. 'Farmer variety' represents the relative ranking farmers gave to an indigenous matooke variety. 'Modern variety' refers to the relative ranking farmers gave a conventional or non-GM hybrid matooke variety. 'GM farmer variety' refers to the relative ranking farmers gave to a GM matooke when a Ugandan indigenous variety acts as the host. 'GM modern variety' refers to the relative ranking farmers gave to GM matooke when a conventional variety acts as the host.

$^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

(p=0.102) and D (p=0.376). For Future Scenario C ('are you concerned about health consequences?'), membership in a farmers' organization significantly impacted responses χ^2 (N=162)=6.96, p=0.008. Farmers who are members of an association are significantly more concerned about health consequences of GM technology (86.1%=yes) than those who are non-members (68.7%=yes).

Overall, our results suggest that belonging to a farmers' association positively influences farmer attitudes and intentions to adopt GM matooke banana. These findings resonate with recent studies that highlight the importance of social networks on the uptake of new technologies (Gonsalves, Lee, & Gonsalves, 2007; Maertens & Barrett, 2012; Matuschke & Qaim, 2008; Saweda, Liverpool-Tasie, & Winter-Nelson, 2012). Farmers' associations provide important venues where farmers can share information and learn from their peers, and can play an important role in accelerating the adoption of GM varieties (Arechavala-Vargas et al., 2007; Skevas & Wesseler, 2009). In focus groups, farmers elaborated on how such collective associations can accelerate the dissemination of new varieties; farmers in Buikwe District emphasized that they preferred to see the new variety with their own eyes before purchasing it, to guard against being 'cheated' by unfamiliar varieties. Other benefits of such associations are shared knowledge about best practices and management, pooled resources for the purchase of key inputs, as well as access to crucial resources such as labor and tools (Nakaseke District, Kamuli District, Kyenjojo District). But such hubs of information exchange can also cut both ways. As Kabunga, Dubois, and Qaim (2014, p.30) observe, negative attitudes toward new technology can also be spread though such social networks, a point underlined by the high incidence of health concerns among members. Still, on balance, membership in a farmers' association seems to be a positive influence on both attitudes and intentions to adopt GM varieties.

Previous Experience with Improved Varieties

A Mann-Whitney test was used to assess whether previous experience with varieties improved via conventional breeding—such as hybrids and tissue culture—influences farmers' responses to the combined attitudinal and ranking variables.[4] Farmers who have previous experience with improved varieties are significantly more likely to have a positive attitude toward GM technology than those with no previous experience, as reflected in the combined attitudinal variable (U=2320, p=0.028; see Table 5). This finding is supported by results from the ranking exercises. Farmers having no previous experience with improved varieties showed significantly greater preference for non-GM farmer (U=3793, p=0.005) and modern varieties (U=3839, p=0.003) than those with prior experience. In contrast,

4. *In Uganda, improved varieties of matooke are collectively referred to as 'Kawanda varieties,' a reference to their originating at the Kawanda Agricultural Research Laboratory, the national center for all experimental research into banana.*

Table 6. Visits from agricultural extension workers and combined variables.

	Visited by extension workers	N	Mean	Std. deviation	Mann Whitney test statistic (U)
Pro GM attitude	Yes	60	3.87	0.81	2067***
	No	104	3.36	0.88	
Prefers farmer variety	Yes	61	1.67	0.57	3730
	No	106	1.92	0.78	
Prefers modern variety	Yes	61	1.90	0.81	3818
	No	106	2.24	1.00	
Prefers GM farmer variety	Yes	61	3.16	0.79	2637.5*
	No	106	2.86	0.96	
Prefers GM modern variety	Yes	61	3.26	0.56	2460*
	No	106	2.97	0.68	

Note: 'Pro GM attitude' represents farmers' combined scores to the 11 attitudinal statements that measured the extent of agreement with GM technology. 'Farmer variety' represents the relative ranking farmers gave to an indigenous matooke variety. 'Modern variety' refers to the relative ranking farmers gave a conventional or non-GM hybrid matooke variety. 'GM farmer variety' refers to the relative ranking farmers gave to a GM matooke when a Ugandan indigenous variety acts as the host. 'GM modern variety' refers to the relative ranking farmers gave to GM matooke when a conventional variety acts as the host.

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

farmers with previous experience with improved varieties showed significantly greater preference for GM versions of both farmer (U=1924, p<0.001) and modern varieties (U=2173, p=0.003).

We also used a Pearson chi-square test to measure whether previous experience with improved varieties influences responses to the future scenarios. For Future Scenario A, previous experience did not significantly affect responses (p=0.112). For Future Scenario B ('Are you concerned about environmental consequences?'), previous experience significantly affected responses χ^2 (N=156)=4.601, p=0.032. Farmers who have previous experience with improved varieties are significantly more likely to be concerned about environmental consequences (85.7%=yes) than those who have none (71%=yes). For Future Scenario C ('Are you concerned about health consequences?'), previous experience significantly affected farmer's responses χ^2 (N=155)=9.84, p=0.002. Farmers who have previous experience with improved varieties are significantly more likely to be concerned about health consequences (90.3%=yes) compared to those who have none (68.8%=yes). For Future Scenario D there were no significant results (p=0.089).

Overall, our results suggest that farmers with previous experience growing improved varieties have a more favorable view of GM technology, even as they remain concerned about health and environmental consequences. These results are congruent with the more general trend that emerges within the literature: farmers with prior exposure to improved farming technology tend to be more willing to adopt and experiment with new technological advances (Ainembabazi & Mugisha, 2014; Asfaw, Menale, Simtowe, & Lipper, 2012a; Kolady & Lesser 2006; Tambo & Abdoulaye, 2012). Asfaw, Shiferaw, Simtowe, and Lipper (2012b) explain this trend as rooted in farmer technology awareness: farmers who are already familiar with modern varieties are more willing to accept and adopt GM varieties (see also Soleri et al., 2008). Qualitative responses from farmers affirm this interpretation: those farmers who have experience with improved varieties list both their advantages and disadvantages, displaying significant skepticism regarding potential limitations as reflected in the heightened concern around negative environmental or health consequences. These farmers are also forthcoming about the lessons learned from adopting previous improved varieties, particularly with respect to the increased inputs, especially organic fertilizer, that are needed to sustain these larger yields over the long-term (Buikwe District).

Visits from Agricultural Extension Workers

A Mann-Whitney test was used to measure the influence of visits from extension workers on farmer responses to the combined attitudinal and ranking variables. Table 6 shows that farmers who have been visited by extension workers had a significantly more positive attitude toward GM technology than those who have never been visited (U=2067, p<0.001). Visits from extension workers did not significantly influence farmers' rankings of the non-GM farmer (U=3730.5, p=0.095) and improved varieties (U=3818, p=0.050). However, farmers who were visited by extension workers showed significantly greater preference for GM farmer (U=2637.5, p=0.046) and improved (U=2460, p=0.010) varieties.

We used a Pearson chi-square test to measure how visits from extension workers influence responses to the future scenarios. There were no significant results for Future Scenarios A (p=0.197), B (p=0.985) and C (p=0.286). For Future Scenario D ('do you have confidence that governmental institutions can protect you against possible risks associated with this new technology?'), previous visits from extension workers significantly influenced farmers' responses χ^2 (N=164)=5.93, p=0.015. Farmers who have been visited by extension workers have more confidence that government institutions can protect them (78.7%=yes) than those who have not been visited (60.2%=yes).

These findings corroborate previous research that has identified access to extension services as a crucial catalyst for farmer adoption of GM crops (Arechavala-Vargas et al., 2007; Ezezika, Deadman, & Daar, 2013; Torres, Daya, Osalla, Ma, & Gopela, 2013; Zambrano, Smale, Maldonado, & Mendoza, 2012). The positive relationship between access to extension services and the adoption of new technologies has been well documented in Uganda (Kijima, Otsuka, & Sserunkuuma, 2011), as well as in other contexts (Kaliba, Verkuijl, & Mwangi, 2000; Kassie, Shiferaw, & Muricho, 2011; Kristjanson, Okike, Tarawali, Singh, & Manyong, 2005); farmers who are visited by extension agents tend to be more willing to experiment with new, improved varieties. Qualitative data underline the value farmers' place on extension services: many farmers identified a lack of access to extension workers as the most pressing obstacle to the adoption of new technologies. Some representative quotes include 'you cannot do anything without extension workers' (Wakiso District) and 'after extension workers provide knowledge, we are able to manage any other problem' (Isingiro District). A farmer in Buikwe district sums up the critical role that extension workers play in knowledge and technology dissemination: 'everything you need to learn, it's them [extension workers] who teach us.'

But access to extension is distributed unevenly throughout the population. Smaller farmers, poorer farmers, and female farmers tend to be excluded from these services (Arechavala-Vargas et al., 2007; Ezezika et al., 2013). This asymmetrical access echoes concerns made in previously in this article about smaller-scale, poorer farmers being less likely to adopt and potentially benefit from GM matooke. The increased access to extension services is another factor impacting farmer attitudes and intentions to adopt—one that could propel the adoption of GM matooke among wealthy farmers more than poor ones.

Conclusion

If GM matooke is commercialized in Uganda, which farmers are most likely to adopt it? Our findings suggest these technologies are more likely to be adopted by the heavily marketized farmers in the southwestern region. Larger farmers are more likely to adopt than smaller farmers. Membership in a farmers' association, planting improved varieties, and existing relationships with extension agents all increase the likelihood of adoption.

Two policy recommendations emerge from these findings. First, identifying the key variables that shape attitudes and intentions to adopt offers a promising means for policymakers to target demographic pockets of early adopters. When GM matooke is commercialized, research scientists and policy leaders will need to make strategic decisions about where to focus their initial dissemination efforts and how best to encourage widespread adoption. Our results suggest that the rollout should start with the more market-oriented, larger farmers in the southwest region, who appear most enthusiastic about these new varieties. Also, policymakers should aim to capitalize on current farmers' associations, adoption of improved varieties, and existing relationships with extension agents—as farmers who are already have experience and exposure to new knowledge and technologies through these networks seem more willing to embrace GM versions of matooke. These findings offer a useful starting point for strategies of dissemination and adoption, which could be accelerated by agricultural policies that aim to capitalize on these five predictor variables.

The second policy insight is more cautionary. The five variables that significantly impact attitudes and intentions to adopt are all associated with affluence and social influence. These results thus raise important questions about the potential for GM matooke to help the poorest and most vulnerable in the country—those who are disproportionately located in the eastern and central region, with smaller farms, who tend to be excluded from formalized social networks and lack critical access to information. These results underscore the need for targeted policies that are geared toward meeting the needs of those farmers who lack these resources, and the potential risk that these most vulnerable farmers could miss out on the potential benefits associated with GM versions of African carbohydrate staple crops.

More generally, our findings underline the need for agricultural policies and experimental programs that recognize the stratified and differentiated patterns of attitudes and adoption that will follow the commercialization of GM versions of African carbohydrate staple crops. Some farmers will adopt these technologies, others will not. Some farmers will benefit from GM varieties, others will not. This research offers valuable insight into the specific breakdown around which such stratifications will take place in the context of one orphan crop (matooke banana) in one country (Uganda). Policymakers need more nuanced, empirical analyses of whether GM versions of staple crops currently under experimentation match up with the political, economic, and ecological circumstances that farmers encounter on the ground. Ultimately, it will be Africa's farmers who determine whether these GM varieties will be cultivated on the continent. Agricultural policies and experimental programs that recognize and reflect their diverse set of priorities and concerns are urgently needed.

References

Adenle, A.A. (2013). Stakeholders' perceptions of GM technology in West Africa: Assessing the responses of policymakers and scientists in Ghana and Nigeria. *Journal of Agricultural and Environmental Ethics*, *27*(2), 241-263.

Adenle, A.A., Morris, J., & Parayil, G. (2013). Status of development, regulation and adoption of GM agriculture in Africa: Views and positions of stakeholder groups. *Food Policy*, *43*, 159-166.

Adesina, A.A, & Baidu-Forson, J. (1995). Farmers' perceptions and adoption of new agricultural technology: Evidence from analysis in Burkina Faso and Guinea, West Africa. *Agricultural Economics*, *13*, 1-9.

Aerni, P. (2005). Stakeholder attitudes towards the risks and benefits of genetically modified crops in South Africa. *Environmental Science and Policy*, *8*, 464-476.

Ainembabazi, J.H., & Mugisha, J. (2014). The role of farming experience on the adoption of agricultural technologies: Evidence from smallholder farmers in Uganda. *The Journal of Development Studies*, *50*(5), 666-679.

Arechavala-Vargas, R., Díaz-Pérez, C., & Huerta-Ruvalcaba, J.P. (2007). Genetically modified maize in Mexico: Varied responses to technology. In *Proceedings from Atlanta conference on science, technology, and innovation policy 2007*. Atlanta, GA.

Asfaw, S., Menale, K., Simtowe, F., & Lipper, L. (2012a). Poverty reduction effects of agricultural technology adoption: A micro-evidence from rural Tanzania. *The Journal of Development Studies*, *48*(9), 1288-1305.

Asfaw, S., Shiferaw, B., Simtowe, F., & Lipper, L. (2012b). Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. *Food Policy*, *37*, 283-295.

Bellon, M.R., & Reeves, J. (Eds.). (2002). Quantitative analysis of data from participatory methods. Mexico City: International Maize and Wheat Improvement Center (CIMMYT).

Bett, C., Okuro Ouma, J., & De Groote, H. (2010). Perspectives of gatekeepers in the Kenyan food industry towards genetically modified food. *Food Policy*, *35*, 332-340.

Ceccarelli, S., & Grando, S. (2007). Decentralized participatory plant breeding: An example of demand driven research. *Euphytica*, *155*, 349-360.

Chong, M. (2005). Perception of the risks and benefits of Bt eggplant by Indian farmers. *Journal of Risk Research*, *8*(7), 617-634.

Consmuller, N., Beckmann, V., & Petrick, M. (2010). An econometric analysis of regional adoption patterns of Bt maize in Germany. *Agricultural Economics*, *41*(3-4), 275-284.

Cook, A., & Fairweather, J.R. (2003). New Zealand farmer and grower intentions to use gene technology: Results from a resurvey. *AgBioForum*, *6*, 120-127. Available on the World Wide Web: http://www.agbioforum.org.

Dawson, I.K., Hedley, P.E., Guarino, L., & Jaenicke, H. (2009). Does biotechnology have a role in the promotion of underutilised crops? *Food Policy*, *34*(4), 319-328.

Edmeades, S., & Smale, M. (2006). A trait-based model of the potential demand for a genetically engineered food crop in a developing country. *Agricultural Economics*, *35*, 351-361.

Ezezika, O.C., Deadman, J., & Daar, A.S. (2013). She came, she saw, she sowed: Re-negotiating gender-responsive priorities for effective development of agricultural biotechnology in Sub-Saharan Africa. *Journal of Agricultural and Environmental Ethics*, *26*, 461-471.

Gonsalves, C., Lee, D.R., Gonsalves, D. (2007). The adoption of genetically modified papaya in Hawaii and its implications for developing countries. *The Journal of Development Studies*, *43*(1), 177-191.

Hall, C. (2008). Identifying farmer attitudes towards genetically modified (GM) crops in Scotland: Are they pro- or anti-GM? *Geoforum*, *39*, 204-212.

Ho, P., Zhao, J.H., & Xue, D. (2009). Access and control of agrobiotechnology: Bt cotton, ecological change and risk in China. *Journal of Peasant Studies*, *36*, 345-364.

Hopkins, P.E. (2007). Thinking critically and creatively about focus groups. *Area*, *39*(4), 528-535.

Ivankova, N.V., Creswell, J.W., & Stick, S.L. (2006). Using mixed-methods sequential explanatory design: From theory to practice. *Field Methods*, *18*(1), 3-20.

Kabunga, N.S., Dubois, T., & Qaim, M. (2014). Impact of tissue culture banana technology on farm household income and food security in Kenya. *Food Policy*, *45*, 25-34.

Kaliba, A.R.M., Verkuijl, H., & Mwangi, W. (2000). Factors affecting adoption of improved maize seeds and use of inorganic fertilizer for maize production in the intermediate and lowland zones of Tanzania. *Journal of Agriculture and Applied Economics*, *32*(1), 35-47.

Kalyebara, M.R., Wood, S., & Abodi, P.N. (2007). Assessing the potential impact of selected technologies on the banana industry in Uganda. In M. Smale & W.K. Tushemereirwe (Eds.), *An economic assessment of banana genetic improvement and innovation in the Lake Victoria region of Uganda and Tanzania* (Research Report No. 155, pp.141-153). Washington, DC: International Food Policy Research Institute (IFPRI).

Kassie, M., Shiferaw, B., & Muricho, G. (2011). Agricultural technology, crop income, and poverty alleviation in Uganda. *World Development*, *39*(10), 1784-1795.

Kijima, Y., Otsuka, K., & Sserunkuuma, D. (2011). An inquiry into constraints on a green revolution in Sub-Saharan Africa: the case of NERICA rice in Uganda. *World Development*, *39*(1), 77-86.

Kikulwe, E.M. (2010). *On the introduction of genetically modified bananas in Uganda: Social benefits, costs and consumer preferences* (Ph.D.Thesis). Netherlands: Wageningen University.

Kikulwe, E.M., Birol, E., Wesseler, J., & Falck-Zepeda, J. (2011a). A latent class approach to investigating demand for genetically modified banana in Uganda. *Agricultural Economics*, *42*, 547-560.

Kikulwe, E.M., Wesseler, J., & Falck-Zepeda, J. (2011b). Attitudes, perceptions, and trust. Insights from a consumer survey regarding genetically modified banana in Uganda. *Appetite*, *57*, 401-413.

Kimenju, S.C., & De Groote, H. (2008). Consumer willingness to pay for genetically modified food in Kenya. *Agricultural Economics*, *38*(1), 35-46.

Kristjanson, P., Okike, I., Tarawali, S., Singh, B.B., & Manyong, V.M. (2005). Farmers' perceptions of benefits and factors affecting the adoption of improved dual purpose cowpea in the dry savannas of Nigeria. *Agricultural Economics*, *32*(2), 195-210.

Kolady, D.E., & Lesser, W. (2006). Who adopts what kinds of technologies? The case of Bt eggplant in India. *AgBioForum*, *9*(2), 94-103. Available on the World Wide Web: http://www.agbioforum.org.

Kushwaha, S., Musa, A.S., Lowenberg-DeBoer, J., & Fulton, J. (2008). Consumer acceptance of genetically modified (GM)—Cowpeas in Sub-Sahara Africa. *Journal of International Food & Agribusiness Marketing*, *20*(4), 7-23.

Lewis, C.P., Newell, J.N., Herron, C.M., & Nawabu, H. (2010). Tanzanian farmers' knowledge and attitudes to GM biotechnology and the potential use of GM crops to provide improved levels of food security. A qualitative study. *BMC Public Health*, *10*, 407-416.

Loureiro, M.L., & Bugbee, M. (2005). Enhanced GM foods: Are consumers ready to pay for the potential benefits of biotechnology? *Journal of Consumer Affairs*, *39*(1), 52-70.

Maertens, A., & Barrett, C. B. (2012). Measuring social networks' effects on agricultural technology adoption. *American Journal of Agricultural Economics*, *95*(2), 353-359.

Matuschke, I., & Qaim, M. (2008). Seed market privatisation and farmers' access to crop technologies: The case of hybrid pearl millet adoption in India. *Journal of Agricultural Economics*, *59*(3), 498-515.

Ministry of Finance and Planning and Economic Development, Government of Uganda. (2010). *National development plan (2010/11-2014/15)*. Kampala: Government of Uganda.

Paarlberg, R. (2008). *Starved for science: How biotechnology is being kept out of Africa*. Cambridge, Massachusetts and London: England Harvard University Press.

Pini, B. (2002). Focus groups, feminist research and farm women: Opportunities for empowerment in rural social research. *Journal of Rural Studies*, *18*, 339-351.

Pratt, G. (2002). Studying immigrants in focus groups. In P. Moss (Ed.), *Feminist geography in practice* (pp. 214-229). Oxford: Blackwell Publishers.

Saweda, L., Liverpool-Tasie, O., & Winter-Nelson, A. (2012). Social learning and farm technology in Ethiopia: Impacts by technology, network type, and poverty status. *The Journal of Development Studies*, *48*(10), 1505-1521.

Schnurr, M.A. (2013). Bio-hegemony and biotechnology in Uganda: Unraveling the strategies used to promote genetically modified crops into new African markets. *Journal of Peasant Studies*, *40*(4), 639-658.

Schoenbrun, D. (1993). Cattle herds and banana gardens: The historical geography of the Western Great Lakes region, ca AD 800-1500. *The African Archaeological Review*, *11*, 39-72.

Skevas, T., & Wesseler, J. (2009). Coping with ex-ante regulations for planting Bt maize: The Portuguese experience. *AgBioForum*, *12*(1), 60-69. Available on the World Wide Web: http://www.agbioforum.org.

Skevas, T., Kikulwe, E.M., Papadopoulou, H., Skevas, I., & Wesseler, J. (2012). Do European Union farmers reject genetically modified maize? Farmer preferences for genetically modified maize in Greece. *AgBioForum*, *15*(3), 242-256. Available on the World Wide Web: http://www.agbioforum.org.

Smale, M., & De Groote, H. (2003). Diagnostic research to enable adoption of transgenic crop varieties by smallholder farmers in Sub-Saharan Africa. *African Journal of Biotechnology*, *2*, 585-595.

Soleri, D., Cleveland, D.A., Cuevas, F.A., Fuentes, M.R., Rios, H.L., & Sweeney, S.H. (2005). Understanding the potential impact of transgenic crops in traditional agriculture: Maize farmers' perspectives in Cuba, Guatemala and Mexico. *Environmental Biosafety Research*, *4*, 141-166.

Soleri, D., Cleveland, D.A., Glasgow, G., Sweeney, S.H., Cuevas, F.A., Fuentes, M.R., & Rios, H.L. (2008). Testing assumptions underlying economic research on transgenic food crops for third world farmers: Evidence from Cuba, Guatemala and Mexico. *Ecological Economics*, *67*, 667-682.

Stephens, R. (2013). *A history of African motherhood: The case of Uganda 700-1900*. Cambridge: Cambridge University Press.

Tambo, J.A., & Abdoulaye, T. (2012). Climate change and agricultural technology adoption: The case of drought tolerant maize in rural Nigeria. *Mitigation and Adaptation Strategies for Global Change*, *17*, 277-292.

Thompson, J., & Scoones, I. (2009). Addressing the dynamics of agri-food systems: An emerging agenda for social science research. *Environmental Science and Policy*, *12*, 386-397.

Torres, C.S., Daya, R.A., Osalla, Ma, T.B., & Gopela, J.N. (2013). Adoption and uptake pathways of GM/Biotech crops by small-scale, resource-poor Filipino farmers. Los Baños, Laguna, Philippines: College of Development Communication, International Service for the Acquisition of Agri-biotech Applications (ISAAA) SEAsiaCenter, and SEAMEO Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA).

Varshney, R.K., Ribaut, J.M., Buckler, E.S., Tuberosa, R., Rafalski, J.A., & Langridge, P. (2012). Can genomics boost productivity of orphan crops? *Nature Biotechnology*, *30*(12), 1172-1176.

Weinhold, D., Killick, E., & Eustáquio, J.R. (2013). Soybeans, poverty and inequality in the Brazilian Amazon. *World Development*, *52*, 132-143.

Zambrano, P., Smale, M., Maldonado, J.H., & Mendoza, S.L. (2012). Unweaving the threads: The experiences of female farmers with biotech cotton in Colombia. *AgBioForum*, *15*(2), 125-137. Available on the World Wide Web: http://www.agbioforum.org.

Appendix

Attitudinal Statements

The following statements were measured using a five-point Likert scale (with 1=strongly disagree, and 5=strongly agree)

1. I would plant a GM matooke sucker if it cost the same price as a non-GM matooke sucker.

2. I would plant a GM matooke sucker if it cost more than a non-GM matooke sucker.

3. I would plant a GM matooke sucker if it cost the same price as a non-GM matooke sucker, but the banana was more nutritious.

4. I would plant a GM matooke sucker if it cost the same price as a non-GM matooke sucker, but the banana had greater resistance to banana bacterial wilt disease.

5. I would plant a GM matooke sucker if it cost the same price as a non-GM matooke sucker, but the banana had greater resistance to black sigatoka virus.

6. I would plant a GM matooke sucker if it cost the same price as a non-GM matooke sucker, but the banana had greater resistance to nematodes.

7. I would plant a GM matooke sucker if it cost the same price as a non-GM matooke sucker, but it had greater resistance to fusarium wilt.

8. I am confident that the risks associated with GM crops can be avoided.

9. Harmful environmental effects of GM crops are likely to appear in the future.*

10. Harmful human health effects of GM crops are likely to appear in the future.*

11. Even though GM crops may have advantages, it is basically against nature.*

12. Eating GM crops would harm me and my family.*

*Indicates reverse coded items.

Acknowledgements

This research could not have been completed without the exemplary work of our research assistants based in Uganda (Sarah Mujabi-Mujuzi, Miiro Tonny, and Atwooki Rodgers) and Canada (Kelly Pickerill and Alanna Talyor). We are greatly indebted to their insights and commitment to the success of this work. Sean P. Mackinnon (http://savvystatistics.com) was the statistical consultant for this article. We greatly appreciate his assistance with the data analyses. Funding for this research was provided from the John Templeton Foundation and the Social Sciences and Humanities Research Council of Canada.