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Assessment of Public Perception, Awareness and Knowledge on Genetically Engineered Food Crops and their Products in Trans-Nzoia County, Kenya

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Biotechnology has been widely acknowledged as a modern tool that holds the potential to improve agricultural production. Adoption of genetically modified (GM) crops could contribute toward alleviating food insecurity in Kenya, but the attitudes and perceptions of stakeholders are crucial to the acceptance of GM products. The aim of this study was to assess public perceptions of GM crops and foods in Trans-Nzoia County, Kenya. A semi-structured questionnaire survey was conducted with 179 respondents, including 55 farmers and 124 consumers, in both rural and urban areas. The results were analyzed to determine predictors for the willingness to produce and consume GM crops and food products. Farmers' and consumers' perceptions influenced their approval of the use of GM technology. The results indicate that gender, basic knowledge of GM technology, and information access and dissemination are likely to influence the adoption of GM technology by farmers. Consumers who are familiar with government policy and have basic knowledge and share information on GM crops are more likely to approve of the technology than those who do not. Farmers were concerned with the environmental risks associated with GM technology and its possible effect on marketing crops both locally and abroad. Consumers expressed concerns about possible health risks, the ability of the government to protect them, and the acceptance of GM products in the local market. Disapproval of GM products by both farmers and consumers was influenced by the perception of high risks and low benefits. The findings of this study can help policymakers when designing public awareness and risk-communication strategies targeting farmers and consumers to address potential concerns when promoting the use of GM technology.

Key words: Genetically modified crops, farmers, consumers, perception, Trans-Nzoia County

Introduction

The area planted in genetically modified (GM) crops has increased substantially over the past 10 years. In 2009, 14 million farmers worldwide planted GM crops on approximately 134 million ha, 46% of which was in developing countries (James, 2009; Brooks and Barfoot, 2011). Argentina, Brazil, China, India, and South Africa contributed approximately 40% of the global total or 46 million ha in 2008 (James, 2008). During the last 14 years, GM technology has made important positive socioeconomic and environmental contributions. The major impact has been on commercialized agronomic traits in a small range of crops. The major GM crops commercialized globally are soybeans, corn, cotton, and canola, which account for 52 %, 30%, 13%, and 5% of total GM crops grown (by area), respectively (Brooks and Barfoot, 2011).

While GM crops have been widely accepted in the Americas and many Asian countries, acceptance has lagged in European countries and Japan primarily because of consumer concerns about the potential harm to human health, damage to the environment, and a general unease about the "unnatural" nature of the technology (Nuffield Council on Bioethics, 2003; FAO, 2004). These concerns have been exported to Africa through various channels (Paarlberg, 2002, 2008), and each country has developed a regulatory framework to consider costs, benefits, and other concerns in relation to their own specific situations.

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In Africa, only Burkina Faso, Egypt, and South Africa use commercialized GM crops, and Kenya, Nigeria, and Uganda are testing GM crops in confined field trials (Karembu *et al*., 2009). Ghana, Mozambique, and Tanzania also have ongoing GM crop research activities, particularly on staple foods. GM technology is anticipated to produce food crops that will be cheaper and more readily available because of improved yields and more stable production.

Agricultural biotechnology and GM crops are controversial, however; the technology is hailed as having the potential to alleviate world hunger but is also criticized as being dangerous. The latter concerns have induced debates about the safety of these crops and hence have slowed acceptance. The adoption of GM crops has been negatively affected by public opinion and anti-GM lobby groups despite the potential for increased food production in developing countries (Nuffield Council on Bioethics, 2003). Environmental risks such as gene flow, evolution of resistance in the targeted pest populations, impacts on nontarget organisms, and food safety are often raised (Smale and De Groote, 2003).

Several studies have been conducted to assess consumer attitudes and perceptions toward GM crops (Bett *et al*., 2010; Kimenju and De Groote, 2008; Onyango *et al*., 2006). Results reveal that consumers' perceptions toward the potential benefits and risks of GM crops are still mixed and differ within and across countries. Moreover, consumer attitudes toward GM crops change as consumers are exposed to new information (Smale *et al*., 2009). Hence, information has a crucial impact on consumers' preferences for GM food products. Smale *et al*. (2009) also highlighted the general lack of empirical studies integrating consumers' preferences with farmers' adoption of GM crops in developing countries; that is, the propensity to purchase and the propensity to adopt have not been linked in a single study.

Available scientific knowledge and reviews by national and international science organizations on human health indicate that GM foods are safe and suitable for human consumption (FAO, 2004; ICSU, 2004). Despite these assurances, a number of studies show that consumers in developed countries consistently prefer non-GM foods (Costa-Font *et al*., 2008; Lusk *et al*., 2005). In Europe, the potential benefits are generally small, and consumers are worried about the quality and safety of their food system. In addition, trade barriers offer protection to local farmers (Demont *et al*., 2004), and as a result, regulatory systems have been established as a precaution (McMahon, 2003). Although stagnating food crop yields make potential gains from GM technology very important in Africa, particularly in Kenya, strong cultural, political, and economic ties with European countries have caused many African countries to copy European regulatory frameworks (Paarlberg, 2008).

In Kenya, the government developed a working policy document (NCST, 1998) and passed a biosafety bill in parliament in 2009. The law puts in place a rather stringent regulatory framework making the commercial production of GM products possible. The law was the result of a robust debate involving four major players: the government, represented mostly by the Ministry of Science and Technology, the Ministry of Agriculture, and members of parliament; nongovernmental organizations (NGOs); the scientific community, including both public and private research institutes and universities; and civil society. The government and the scientific community were strong proponents of the bill, whereas many NGOs and private individuals, supported by some members of parliament, were strong opponents. The parliamentarian views were mixed, although the proponents prevailed with the eventual passage of the bill. Currently, the status of GM crops in Kenya lies between plant development and seed production, with trials being conducted in contained laboratories and greenhouses. Ongoing GM crop research activities include incorporating traits for insect resistance in maize, insect resistance in cotton, and cassava mosaic disease and viral disease resistance in sweet potato (Karembu *et al*., 2009).

Given their unstable food situation, Kenyan consumers are more likely to be concerned with obtaining sufficient food rather than with the perceived risks of GM products. A study of urban consumers in Kenya revealed that even though GM maize would be widely accepted by consumers, they were also concerned about potential impacts on biodiversity and nontargeted insects (Kimenju and De Groote, 2008). Bett *et al*. (2010) reported that the Kenyan food industry gatekeepers (millers and supermarkets) generally appreciated the potential benefits from GM maize, but also expressed concerns about the environment as well as human and animal health safety. Most studies, however, have addressed the perception of GM products by urban consumers who usually are not producers. There is lack of research on the perception of producers (who are themselves also consumers) of staple crops. The current study links both sides of the market by incorporating farmers (adopters) and non-producing consumers to examine their opinions of the introduction of GM staple foods in Kenya.

Consumers can play a major role in the success or failure of GM crops and products (Biotechnology Australia, 2005). Consumers who are reluctant to accept GM foods are typically more risk conscious and exhibit attitudes favoring slower technology innovation in the food sector (Costa-Font *et al*., 2008). Importantly, consumers often do not regard GM products as being equivalent to conventional products, which confirms earlier arguments that GM foods can cause market failure if GM foods are not labeled (Carlsson *et al*., 2004). More significantly, the study concluded that consumers disagree with assertions by scientists and policymakers that most of today's GM foods are indistinguishable from non-GM foods.

A review conducted by the International Food Policy Research Institute found only 14 consumer studies on GM foods in developing countries, mostly in Asia and a few in South America (Smale *et al*., 2006). Only a few studies of consumer acceptance of GM foods in Africa have been published. A study of urban maize consumers in Kenya revealed that only 38% were aware of GM crops but 67% would buy GM maize at the same price as conventional maize (Kimenju and De Groote, 2008). These Kenyan consumers were often concerned about the loss of biodiversity and the associated impacts on nontarget insects. The study concluded that GM technology has a role to play in improving food security in Kenya, but there is a need to provide more information to consumers about the technology through established sources of information. A second study on consumer acceptance, this time of GM cowpea in urban centers of northern Nigeria, had quite different results: 90% of the respondents were aware of GM products but 67% disapproved of its use (Kushwaha *et al*., 2004). Respondents who were most concerned about the ethics of genetic transformation were likely to disapprove of such products, whereas those who identified international radio as an information source were more likely to approve of GM technology. Other consumer studies in Africa indicate very low awareness of GM foods among rural and urban consumers in South Africa (Vermeulen *et al*., 2004) and among rural consumers in Kenya (De Groote *et al*., 2009).

The Insect Resistant Maize for Africa project, a collaborative effort between the International Maize and Wheat Improvement Centre and the Kenya Agricultural Research Institute (KARI), has been developing GM maize varieties by incorporating modified genes with constitutive expression derived from the soil-dwelling bacteria *Bacillus thuringiensis* (Bt) (Mugo *et al*., 2005). Maize is the major staple food for the majority of Kenyans, but the average yield is low as compared to the average in industrialized countries (2.3–4.5 vs. 8.3 t/ha; Wambugu and Wafula, 2000). Low yields are caused by stem borer infestations, low levels of fertilizer application, and frequent droughts. Kenya loses an estimated 13.5% of its maize production to stem borers annually (De Groote, 2002). As a result, Kenya is a net importer of maize, with an annual average of 400,000 t.

A semi-structured questionnaire survey was conducted of 179 farmers and consumers from rural and urban areas in Trans-Nzoia County, Kenya to (1) assess public perceptions of and knowledge about GM products and their impact on decisions to adopt and consume these products; (2) investigate consumers' willingness to purchase GM crops and foods and factors influencing consumer purchasing behavior; and (3) identify the factors that influence consumers' attitudes and perceptions towards GM crops and foods. Factors hypothesized to influence willingness to approve use of GM technology were risk/benefit perceptions and information source. The effect of individual characteristics such as gender, age, knowledge, and education were also examined.

Materials and Methods

The Study Area

Trans-Nzoia County is one of 14 counties located in the north rift region of the Rift Valley Province of Kenya (Fig. 1). Trans-Nzoia County has three administrative districts: Trans-Nzoia East, Trans-Nzoia West, and Kwanza. The county is further subdivided into eight administrative divisions: Kaplamai, Cherangany, Saboti, Kiminini, Central, Waitaluk, Kwanza, and Endebess.

The county covers an area of 2487 km^2 of which about 2000 km^2 is arable land. The main topographical features in the county are Mt. Elgon (4313 m) to the west, the Cherangani Hills (3371 m), and the Nzoia

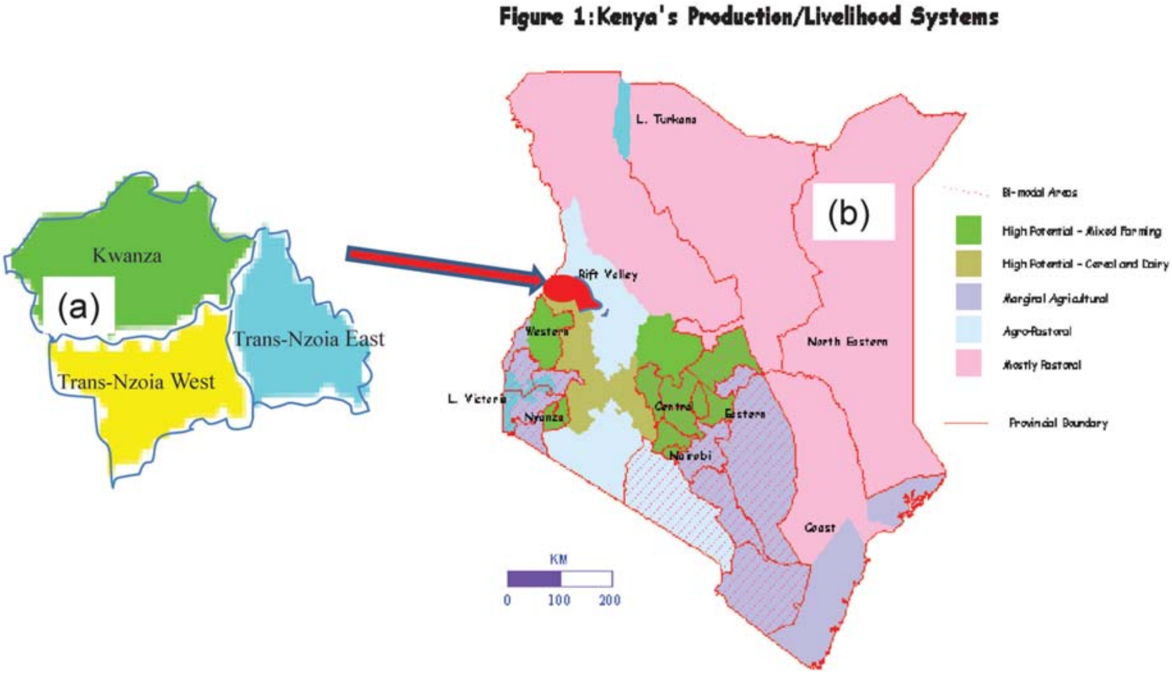

Fig. 1. (a) Location of Trans-Nzoia County (b) Map of Kenya's Livelihood Systems (Source: Mutunga and Oduor, 2003)

River, which flows into Lake Victoria. The county has a highland equatorial climate with an average annual rainfall of 700 to 2100 mm. The temperature ranges from 11 to 25℃. Generally, the district is flat with an elevation of 1800 m a.s.l. The Kitale-Endebess plain, which covers about 50% of the county, is the best area for farming maize and sunflower. The county is cosmopolitan and has been settled by people from most ethnic communities in the country, including Luhya, Kikuyu, Kisii, Kalenjin, and Pokot. The total population is 818,757 and about 54% of the population lives in absolute poverty (KNBS, 2009).

Agriculture is the main economic activity in the county. The main food crops are maize, beans, potatoes, sweet potatoes, sorghum, cassava, and millet. Wheat, coffee, seed maize, and sunflower are the main cash crops. Horticulture is a major enterprise, and vegetables, fruits, nuts, and flowers are produced for both local and export markets. Fruits, vegetables, and flowers are exported mainly to the European Union and macadamia nuts are exported to Japan. Dairy farming is widely practiced as a source of food and income. Although the county has enormous potential to produce enough food, many farmers are still vulnerable in terms of food security.

Data collection and analysis

A cross-sectional survey design was used to collect qualitative and quantitative data on socioeconomic status and individual perceptions of GM crops and foods. Participants drawn from rural and urban areas in six divisions of the county were interviewed using a semi-structured questionnaire (Appendix 1). Twelve agricultural extension officers in the study area administered face to face interviews in January 2011 after I trained them. There were 179 valid responses out of 200 administered questionnaires: 55 from farmers and 124 from consumers (businessmen, teachers, students, extension agents, and other private individuals). A list of locations within the divisions which ensured rural, urban, farmers and consumers respondents were represented was prepared prior the survey. Locations and respondents within the selected areas were then randomly selected.

Awareness of biotechnology was captured by asking the respondents whether they had heard or read about biotechnology and GM crops in general. Respondents who were aware of and understood these concepts were asked to either agree or disagree with follow-up statements about GM crops. Respondents who indicated they had heard about GM technologies were also asked about their major sources of information and whether they shared information on GM crops with family, neighbors, and others.

Responses were analyzed using descriptive statistics to assess the level of knowledge and perception of both farmers and consumers. In addition, a limited dependent variable model was specified to predict the probability that an individual, given his or her characteristics and socioeconomic attributes, would be willing to adopt or consume GM crops and foods. This model assumes that, in making such a decision or commitment, an individual possesses a utility ranking (y^*), which is unobserved and that the individual will be willing to consume or adopt GM crops or farm produce if his or her utility ranking surpasses a threshold level. The model can be stated as follows:

$$Y_i = \beta_0 + \beta_1 GENDER + \beta_2 HHS_i + \beta_3 AGE_i + \beta_4 EDU_i + \beta_5 MONINCO_i + \beta_6 TRUSCI_i + \beta_7 KNGM_i + \beta_8 OPBIOT_i + \beta_9 FSEC_i + \beta_{10} INFS_i + \varepsilon_i$$

where $Y_i = 1$ if $y^* >$ the threshold value and $Y_i = 0$ if $y^* \leq$ the threshold value. The β values represent model coefficients, measuring the marginal impact of each explanatory variable. ε is a random error term, and the index i represents an individual respondent. The explanatory variables are defined as follows:

GENDER has a value of 1 if the respondent is female and 0 if the respondent is male.

HHS is the number of persons in the household.

AGE represents the respondent's age in years.

EDU measures education level of the respondent (number of years in formal schooling).

MONINCO is the respondent's monthly income in Kenya shillings (Ksh.).

TRUSCI takes a value of 1 if respondents trust scientific applications from scientists and if 0 otherwise.

KNGM takes a value of 1 if respondents have basic knowledge of application of GM technology in crop/food development and 0 if otherwise.

OPBIOT takes a value of 1 if respondents are positive about consumption of crops/foods developed by GM technology and 0 if otherwise.

FSEC takes a value of 1 if respondents believe GM technology can result in food and nutritional security and 0 if otherwise.

INFS takes a value of 1 if respondents approve of the information shared about the use of GM technology in crop/food development and 0 if otherwise.

The dependent variable WILGM used in the model in this study is the respondents' approval of GM products. The dependent variable was defined to have a value of 1 if the respondents answered they were "very willing" or "somewhat willing" to grow or consume GM products, "neither willing nor reluctant" responses were omitted (due to binary restriction) and a value of 0 if they said they were "somewhat reluctant" or "very reluctant". The independent variables used to explain public approval of the use of genetic modification include the socioeconomic and value attributes of the consumers or farmers. Most are listed above, but the following attributes were also considered:

LOC was respondents' location of residence was classified on the basis of where they lived, where rural takes a value of 2 and 1 if urban.

LANDSZ was land size of land owned and cultivated for potential GM crops (in ha).

POLGM represented policy on GM regulation: This takes a value of 1 if respondents are aware of policy regulation and 0 if otherwise.

Once data harmonization was completed by dropping "neither willing nor reluctant", the probability that $Y_i = 1$ could be estimated by a particular cumulative distribution function for the model. A probit model was used, and assuming a cumulative distribution function for a standard normal variable Y_i, estimation of the probit model yielded values for the model coefficients. A regression analysis was conducted on obtained data using Gretl software version 1.1 (Gretl Software Version 1.1, 2011).

Perception was assessed by asking respondents whether they agreed with statements on risks and benefits associated with GM crops using a five-point Likert scale (strongly disagree, disagree, neither agree nor disagree, agree, strongly agree). The statements were organized into five categories: environmental risks, health risks, trust in government, local marketing of GM products, and exporting GM products. To analyze the respondents' level of agreement with the different statements on GM technology, responses were weighted (−1 for strongly disagree, −0.5 for disagree, 0 for neither agree nor disagree, 0.5 for agree, and 1 for strongly agree), and the average "perception" scores were calculated for each statement and category of respondent. An overall perception index was calculated for each of these categories by taking the mean of the scores in each category.

Results and Discussion

Survey results and summary statistics

A majority of farmers (49%) indicated that they would like GM technology to address increased yields, 23% wanted reduced diseases and pests, and 18% wanted increased drought tolerance (Fig. 2). In terms of nutrients, consumers preferred the enhancement of the protein content (51%), followed by vitamins (32 %), carbohydrates (10%), and oil (7%) in crops and staple foods (Fig. 3). These results suggest that these traits should be targets of improvement by GM technology. The main source of information on GM technology for farmers is newspaper articles (43%), extension officers (34%), radio (12%), and television (10%). Consumers receive most of the information from newspapers (32%), radio (29%), extension officers (27%), and television (13%). Summary statistics for the independent variables are presented in Tables 1 and 2.

Model estimation and empirical results

Two probit models were estimated to explain GM technology approval among farmers and consumers. The estimated model coefficients, associated z-ratios, and marginal effects of the explanatory variables for farmers and consumers are reported in Table 3 and Table 4, respectively. The tables also report estimated values of log-likelihood functions, chi-squared statistics of model significance, and model success rate prediction.

Among farmers, the gender coefficient was negatively related to approval ($p<0.05$), indicating that female respondents had a more negative attitude towards GM products and males had a more positive attitude towards them. These results are consistent with the findings of previous studies, which have shown that males generally have more positive attitudes toward science and technology than females (Hoban, 2004). Females, especially from developing countries, are generally less knowledgeable, less interested, and less supportive of science and technology than males (Anunda *et al*., 2010). Mucci *et al*. (2004) studied consumer perception and purchase intentions for GM foods in Argentina and found out that GM food was more acceptable to male consumers than to females. Christoph *et al*. (2008) examined consumer attitudinal clusters based on acceptability of genetic modification in Germany and found that GM supporters tended to be older and were more often male than female. Similar studies done in the United States found that women are less supportive of GM crops and foods than their male counterparts (Hossain *et al*., 2002). In another study, Siegrist *et al*. (2000) related gender differences on GM foods with benefit perceptions.

The coefficient of knowledge of GM technology (KNGM) was positively related to approval ($p<0.05$), indicating that the respondent's basic knowledge of GM is likely to influence the approval of GM technology by farmers. Perception of risk and benefits is a dynamic process, and this dynamism can be motivated by an increased knowledge of GM products (Bredahl *et al*., 1998). There is a direct and positive relation between increasing knowledge of GM technology and increasing support for GM applications (Koivisto-

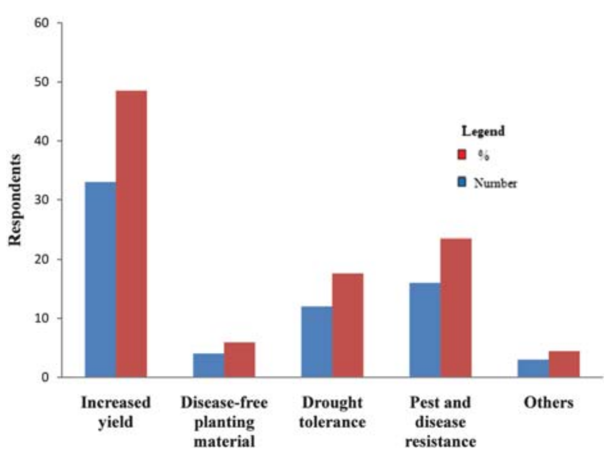

Fig. 2. Production constraints farmers would like GM technology to address.

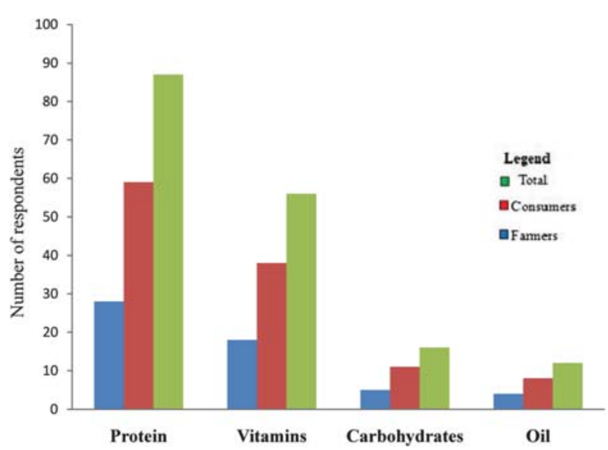

Fig. 3. Food and nutritional attributes farmers and consumers would like GM technology to increase or optimize.

Table 1. Descriptive statistics for farmers (adopters)

Variable	Description	Mean	Std. dev.
GENDER	1=Female; otherwise 0	0.24	0.43
HHS	Household size	6.90	2.73
AGE	Age in years	49.3	12.69
EDU	Education years	11.1	0.13
MONINCO	Monthly income in Ksh (Kenya shillings)	10,351	12,221
TRUSCI	Trust science application; otherwise 0	0.87	0.34
KNGM	1=Basic knowledge of GM; otherwise 0	0.58	0.50
FSEC	1=GM can ensure food security; otherwise 0	0.87	0.34
INFS	1=Share GM info; otherwise 0	0.85	0.34
LOC	1=Urban; 2=Rural	1.02	0.12
LANDSZ	Land area cultivated (Ha)	3.98	5.46
POLGM	1=Policy aware; otherwise 0	0.93	0.26
WILGM	1=Willingness to grow GM; otherwise 0	0.60	0.49

Note: Kenya shillings; 80 Ksh=$ 1

Table 2. Descriptive statistics for consumers

Variable	Description	Mean	Std. dev.
GENDER	1=Female; otherwise 0	0.29	0.46
HHS	Household size	4.21	3.18
AGE	Age in years	39.80	13.56
EDU	Education in years	13.17	2.90
MONINCO	Monthly income in Ksh (Kenya shillings)	12,587	12,837
KNGM	1=Know GM; otherwise 0	0.84	0.37
FSEC	1=Food secure otherwise 0	0.88	0.36
INFS	1=Share info; otherwise 0	0.96	0.20
LOC	1=Urban; 2=Rural	0.45	1.72
POLGM	1=Policy; otherwise 0	0.65	0.50
WILGM	1=Will consume; otherwise 0	0.92	0.52

Note: Kenya shillings; 80 Ksh=$ 1

Hursti and Magnusson, 2003), and both subjective and objective knowledge have been found to be important.

Information, awareness, and basic knowledge of GM technology are very important because they determine acceptance of a technology. In a review of the impact of biotechnology information on consumers, Smale *et al*. (2009) found it to be crucial irrespective of the region studied. Consumer attitudes change significantly after absorbing new information, particularly negative information. The process by which individuals acquire information is not straightforward. First, "substantial content" influences acceptance (Bredahl *et al*., 1998), which includes concrete, reliable, accurate, and tangible information. Trust then motivates information updating and hence knowledge acquisition (Costa-Font and Mossialos, 2005).

Approval for GM products increased with age among farmers and consumers, although the results were not significant. The results of previous studies have not been consistent. Olofsson and Olsson (1996) reported that acceptance of GM products increased with age, whereas Koivisto-Hursti *et al*. (2002) demonstrated the opposite.

The results for GM technology approval by consumers are reported in Table 4. The KNGM and POLGM coefficients are positive and significant at the 5% level. Therefore, respondents who have basic knowledge and who have seen, read, or heard about

Table 3. Parameter estimates of farmers' approval of GM technology-probit model

	Coefficient	Std. Error	z	p
Const.	−8.544	4.284	−1.995	0.046**
GENDER	−4.679	2.118	−2.209	0.027**
HHS	0.008	0.175	0.045	0.964
AGE	0.099	0.050	1.959	0.050*
EDU	0.228	0.219	1.041	0.298
MONINCO	0.001	0.001	1.252	0.211
TRUSCI	1.620	1.240	1.304	0.192
KNGM	5.045	2.207	2.286	0.022**
OPBIOT	0.726	1.234	0.588	0.557
FSEC	−0.631	1.392	−0.453	0.650
INFS	−2.940	1.706	−1.724	0.085*

Mean dependent var.	0.800	S.D. dependent var.	0.000
McFadden R-squared	0.735	Adjusted R-squared	0.335
Log-likelihood	7.306	Akaike criterion	36.613
Schwarz criterion	58.693	Hannan–Quinn	45.151

Number of cases correctly predicted=52 (94.5%)
f(beta'x) at mean of independent vars.=0.000
Likelihood ratio test: χ^2 (10)=40.432 [0.000]
Test for normality of residual –
Null hypothesis: error is normally distributed
Test statistic: χ^2 (2)=12.731, p=0.002

Note: (**) indicate variable is significant at $p<0.05$.
f(beta'x) is the variable coefficient under normal distribution.

GM crops are more likely to approve of the use of GM technology to create new food products. Individual attributes, particularly knowledge, can be linked to consumer attitude. The level of awareness was high on preferred food nutrient quality and GM technology. Knowledge about specific GM products and the underlying production process is essential in shaping attitude. It has been shown empirically that there is a direct association between increasing knowledge of GM technology and increasing support for GM applications (Koivisto-Hursti and Magnusson, 2003). The main source of information was newspapers (32%) and radio (29%). Consumers who are aware of government policies on GM crops are also more likely to approve of the technology than those who are not.

Conversely, the coefficient of OPBIOT was negative, which suggests that negative opinion of biotechnology will have a negative influence on approval. Consumers who absorb negative information are more likely to disapprove of GM foods. The results in this study differ from those of a survey conducted by Kimenju *et al*. (2011) that indicated that almost all consumers were willing to use GM maize meal.

The coefficients of gender, household size, age, trust in science and scientists, information sharing, and food security were all positive but not significant, suggesting that they do not significantly influence the opinion of consumers about the approval of GM technology. The estimated log-likelihood functions and chi-squared statistics indicate significant explanatory power for the estimated model, and the model correctly predicted 87.1% of the cases.

Attitude towards GM crops and foods

Risk perception was assessed by asking respondents whether they agreed with statements on risks and benefits associated with GM products and using a five-point Likert scale to rank the responses (Table 5). A higher percentage of farmers expressed concerns about environmental risks posed by GM crops as compared to consumers. Not surprisingly, farmers were also

Table 4. Parameter estimates of consumers' approval of GM technology—probit model

	Coefficient	Std. Error	z	p
Const.	−2.782	1.927	−1.444	0.149
GENDER	0.196	0.379	0.517	0.605
HHS	0.076	0.090	0.843	0.399
AGE	0.017	0.019	0.887	0.375
EDU	0.040	0.066	0.605	0.545
MONINCO	$-3.05e^{-06}$	$1.72e^{-05}$	−0.177	0.859
TRUSCI	0.270	0.567	0.477	0.634
KNGM	1.089	0.436	2.496	0.013**
POLGM	0.852	0.414	2.057	0.040**
INFS	1.419	0.969	1.465	0.143
OPBIOT	−0.621	0.360	−1.727	0.084*
FSEC	0.039	0.446	0.087	0.931

Mean dependent var.	0.853	S.D. dependent var.	0.171
McFadden R-squared	0.233	Adjusted R-squared	−0.015
Log-likelihood	−37.083	Akaike criterion	98.165
Schwarz criterion	131.208	Hannan-Quinn	111.579

Number of cases correctly predicted=101 (87.1%)
f(beta'x) at mean of independent vars.=0.171
Likelihood ratio test: χ^2 (11)=22.505 [0.021]
Test for normality of residual –
Null hypothesis: error is normally distributed
Test statistic: χ^2=1.07532, p=0.58411

Note: (**) indicate variable is significant at $p<0.05$.
f(beta'x) is the variable coefficient under normal distribution.

Table 5. Classification of farmers' and consumers' attitudes and perceptions toward GM products.

Perception	Number respondents who agree (% of the total)[a]		Perception score		Mean score
	Farmers	Consumers	Farmers	Consumers	
Environmental risks	27 (43.5)	85 (37.3)	0.11	−0.69	−0.29
Health risks	12 (18.8)	66 (27)	−0.38	−0.54	−0.46
Trust in government	6 (12.2)	52 (36.5)	−0.49	0.42	−0.04
Marketing of GM locally	3 (5.7)	71 (7)	−0.79	−0.58	−0.69
GM and export market	47 (69.1)	42 (26.9)	0.51	0.34	0.43

[a] Figures in brackets indicate the percentage of total number of farmers or consumers in the given category.

more concerned with the effect of GM technology on the export market. Both farmers and consumers expressed concerns about health risks, although farmers were more optimistic. Conversely, consumers were more optimistic about the government's ability to protect them from any negative effects associated with GM products. Very few farmers and consumers agreed that GM products would be accepted in the local market.

Harrison and House (2004) found that as perceptions of risk to human health and the environment increased, U.S. consumers' willingness to purchase GM foods decreased, and the marginal effects for the risk index indicated that concerns regarding health and environmental risks are the most important factors affecting consumer acceptance in the U.S. In China, consumers with little information about potential health and environmental problems related to GM foods became increasingly conscious after negative reports about human health, biosafety, and the environment appeared in various media outlets (Zhong *et al*., 2006).

Conclusions

The results of this study have important implications for the agricultural industry. Combined with appropriate policies, strategic partnerships, efficient regulatory systems, and effective communication, the application of GM technology has the potential to make a significant contribution towards improving crop productivity and farmers' livelihoods, as well as ensuring environmental sustainability.

Consumer expectations and demands will drive the successful placement of GM products in the market. Similarly, adoption of GM technology by farmers will depend on their approval of the technology. The majority of the respondents in this study had some knowledge of biotechnology but still had a limited understanding of specific areas of concern. Perceived risks on human health and the environment as well as concerns over the loss agricultural commodities markets influenced the level of acceptance. Mass media has been the main source of information dissemination. However, even with these concerns, majority (49%) of farmers would like GM technology to address yield increase hence food and nutritional security. The study may serve as an outreach tool to reach potential consumers and farmers and assist the agricultural industry in developing strategies capable of anticipating changes in market demand relative to product development.

Recommendations

Farmers and consumers will adopt and accept crops or foods developed through GM technology when they have a good understanding of it. Improvement in information sharing and delivery is therefore necessary. The information reaching end users should be informative, easy to understand, and user friendly. Extension service providers targeting the implementation of GM technology to enhance food production should invest in educational campaigns taking into consideration farmer age and prior knowledge of biotechnology, involvement of scientists, information sharing systems, and dissemination channels. Female farmers should be targeted by various means, including language and message packaging.

There is a need for increased public awareness and participation in GM technology at all levels. Priority should be given to developing mechanisms and processes for information sharing and education on biotechnology, biosafety, and intellectual property rights because these are essential to consumer approval and acceptance of the technology. Educational campaigns targeting those with inaccurate knowledge of GM technology will be especially critical. When GM crops are commercialized, demonstration plots in which GM and conventional crops are compared could be very useful in disseminating information. Creating effective linkages between extension agents, scientists, and farmers through workshops and seminars will also enhance understanding and trust between stakeholders. More studies are required from other areas to gain a broader understanding of the attitudes and perceptions of GM technology in Kenya.

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Appendix 1: Sample questionnaire

Section 1: Demographics

1. Name of household head ______________________________
2. Location ______________________________
3. Gender (i) Male (ii) Female
4. Age (i) 18–22 (ii) 23–27 (iii) 28–32
   (iv) 33–37 (v) 38–42 (vi) 43–46
   (vii) 47–52 (viii) More than 53 years.
   State exact age ______________________________
5. Size of household ______________________________
6. Marital status
   i) Single ii) Married iii) Widowed
7. Level of education
   i) None ii) Primary iii) Secondary
   iv) College v) University
8. Location of residence
   i) Urban ii) Rural
9. Which one among the following do you consider as your main means of livelihood ranked from 1 to 4 (4: extremely important, 3: very important, 2: important, and 1: not important)?

   Crop production □ 1 □ 2 □ 3 □ 4

   Livestock production □ 1 □ 2 □ 3 □ 4

   Trading in agricultural products □ 1 □ 2 □ 3 □ 4

   Trading in livestock products □ 1 □ 2 □ 3 □ 4
10. Monthly income in Ksh ______________________________
11. Type of main house

    i) Permanent ii) Semi-permanent (roof, wall and floor made from grass, reeds, mud or timber)
12. Do you think biotechnology could lead to food and nutritional security?

    i) Yes ii) No
13. a) What is the size of the land you farm? (State acreage including rented land; indicate 0 if not a farmer)

    ____

    b) What is the size of the land you own?

i) Small scale (< 0.8 ha) ii) Medium (0.8-2 ha)

ii) Large scale (>2 ha).

Section 2: Awareness, knowledge and attitude towards agricultural biotechnology

14. Do you trust scientists to apply agricultural biotechnology appropriately?

    i) Yes ii) No

15. If yes, what does agricultural biotechnology mean to you?

    ____

16. What is your opinion about agricultural biotechnology?

    i) Positive (explain) ____________________

    ii) Negative (explain) ____________________

17. If yes, what do you think is the worst thing about agricultural biotechnology?

    ____

18. Have you ever read, seen, or heard of genetically modified crops?

    i) Yes ii) No

19. If yes, what does "genetically modified crops" mean to you?

    ____

Section: 3 Status and application of agricultural biotechnology

20. Are you aware of any farmer who is growing a crop developed through agricultural biotechnology?

    i) Yes ii) No

21. If yes, which crop(s)?

    ____

22. In your opinion, what percentages of farmers use agricultural biotechnology crops (tissue culture)?

    i) None ii) Less than 25% iii) 26–50% iv) More than 50%

23. Do you grow a tissue culture crop?

    i) Yes ii) No

24. If yes, what are the benefits of this crop(s)?

    ____

25. Which crop production constraints would you want tackled in biotech (GM) crops?

    i) Increase yield potential ii) Propagation of disease-free planting material

    iii) Drought tolerance iv) Pest and disease resistance v) Other (specify)

26. Which genetically modified products would you prefer to consume?

    i) Maize ii) Banana iii) Sweet potato iv) Other (specify)

27. Which plant product attributes would you prefer increased or optimized?

    i) Proteins (amino acids) ii) Vitamins iii) Carbohydrates iv) Oil content

28. What would discourage you from growing biotech crops?
    i) Availability of seeds or planting materials
    ii) Cost of seeds/planting materials
    iii) Knowledge about planting
    iv) Water requirements
    v) Nutrient requirements (fertilizers or manure)
    vi) Labor demand
    vii) Other (specify)

29. On a scale from 1–5 (where 1 is high and 5 low), rate how willing you are to consume/grow biotech crops.

    1) Very willing
    2) Somewhat willing
    3) Neither willing nor reluctant
    4) Somewhat reluctant
    5) Very reluctant

Section 4: Government policy

30. Are you aware of government programs that encourage use of agricultural biotechnology?

    i) Yes ii) No

31. Are you aware of any government policy on agriculture biotechnology?

    i) Yes ii) No

32. If yes, what does the policy say about agricultural biotechnology?

    ____

Section 5: Impact of agricultural biotechnology

33. Which of the following statements best describes your opinion about the impact of agriculture biotechnology on species diversity in crops?

i) Agriculture biotechnology will increase indigenous crops

(explain)_________________

ii) Agricultural biotechnology will reduce indigenous crops

(explain)_________________

iii) Agricultural biotechnology will have no effect on indigenous crops (explain)

____

34. Which of the following statements best describes your opinion about the impact of agricultural biotechnology on the health of the people?

i) Does not affect the health of the people (explain)

____

ii) Affects the health of the people (explain)

____

iii) Not sure how agricultural biotechnology affects the health of the people (explain) ________________________________

Section 6: Government capacity to manage risks (health)

35. Which statement best describes your opinion about government handling of agricultural biotechnology issues?

i) Government has enough capacity to protect farmers and the general public from the risks associated with agricultural biotechnology

ii) Government does not have the capacity to protect farmers and the general public from risks associated with agricultural biotechnology

iii) Not sure

Section 7: Perceptions about marketing of GM crops and products

36. Which of the following statements best describe your opinion about the marketing of GM products in local markets?

i) Kenyans have accepted GM products

ii) Kenyans do not like GM products

iii) Kenyans do not know enough about GM to have an opinion

37. What is your opinion about effect of GM products in marketing of export crops?

i) Kenyans will lose export markets if they grow GM crops

ii) Kenyans will not lose markets in if they grow GM crops

iii) Don't know

Section 8: Information dissemination and sharing

38. Where do you get information on agricultural biotechnology?

i) Radio

ii) Television

iii) Newspapers

iv) Extension officers

39. How often do you get information on agricultural biotechnology?

i) Daily

ii) Weekly

iii) Monthly

iv) Never

If the answer is never, not why? (Explain)________________________

40. When you learn something new, do you use it and how?

____

41. Do you share it with others?

i) Yes ii) No

42. Who do you share information on agriculture biotechnology with?

i) Family members

ii) Neighbors

iii) Friends

iv) Church members

v) Others (specify) __________________