Journal of Advances in Biology & Biotechnology
9(3): 1-13, 2016; Article no.JABB.28794
ISSN: 2394-1081

SCIENCEDOMAIN *international*
www.sciencedomain.org

Biotechnology and Food Security in Kenya - An Assessment of Public Concerns on Biosafety, Public Health and Religious Ethics

Agnes Mbugua-Gitonga[1*], Francis Mwaura[2] and Thuita Thenya[2]

[1]People for Nature Organization (P4N), Nairobi, Kenya.
[2]Department of Geography and Environmental Studies, University of Nairobi, Nairobi, Kenya.

Authors' contributions

This work was carried out in collaboration between all authors. Author AMG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors FM and TT managed the analyses of the study. Author FM managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JABB/2016/28794
Editor(s):
(1) Laura Pastorino, Laboratory of Nanobioscience and Medical Informatic, Dept. Informatics, Bioengineering, Robotics and Systems Engineering (DIBRIS), University of Genoa, Italy.
Reviewers:
(1) María Eugenia Villalobos Hernández, Universidad Ciencias Médicas (UCIMED), Costa Rica.
(2) Hamit Ayberk, Istanbul University, Turkey.
(3) Obiekea Kenneth Nnamdi, Ahmadu Bello University, Zaria, Kaduna, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/16210

Original Research Article

Received 5th August 2016
Accepted 5th September 2016
Published 16th September 2016

ABSTRACT

Aim: To determine the perceived public concerns on the introduction of maize related agro-biotechnology including genetically modified (GM) maize in Kenya specifically with regard to biosafety, public health and religious ethics.
Study Design: Household survey.
Place and Duration of Study: A small scale maize growing area in Githunguri Ward (Kiambu County), a large maize growing area in Moiben Ward (Uasin Gishu County) and a maize consuming area in Umoja 1 urban residential area in the City of Nairobi, from September to October 2015.
Results: Most of the respondents were concerned about:- a) the likely contamination of conventional crops through cross pollination b) the likely harmful effects of biotechnology on valuable insects, c) the fear of unclear health implications including human sickness and death, and d) the inevitable interference with God's creation of ordinary crops thus undermining God.
Conclusion: There is significant public fear and concern on the introduction of GM crops in Kenya hence the need for increased public education and awareness.

**Corresponding author: E-mail: wambuimbugua@gmail.com;*

Keywords: Biotechnology; food security; GM maize; biosafety; public health and religious ethics.

1. INTRODUCTION

The world population is expected to grow from 7.3 billion to 9.7 billion in year 2050 according to recent forecasts by the United Nations [1]. More than half of the expected growth will occur in Africa, where the population is set to double to 2.5 billion from about 1,218,676,470 in 2016. This projected growth makes food security as one of the most important social issue in the continent for the next 30 years especially in relation to Sustainable Development Goal 2 (SDG-2) of ensuring no hunger, achieving food security and promoting improved nutrition and sustainable agriculture.

In Kenya, the population is expected to double by the year 2050 from about 47 million in 2016 [2]. Consequently, there is a need to increase food production by more than double in order for the country to be food secure. There are numerous ways by which food productivity can be increased in a sustainable way. This includes expansion of food production in arid areas through irrigation. In recent years, biotechnology has also increasingly been considered as a suitable option for this challenge. Currently tissue culture is applied in many countries including Kenya for rapid multiplication of planting materials for vegetatively propagated crops such as coffee, banana, pineapple and root crops [3]. However, only a few countries have adopted GM technology for improved crop production.

The application of biotechnology in food production has generated a wide range of public concerns around the world. A study by [4], for example, established that food consumer organizations, environmentalists and civil society are concerned about GM food on the grounds of food safety, environmental impacts and religious ethics. Based on these concerns, it is likely that inadequate public confidence on the use of biotechnology for sustainable food production may derail the potential socio-economic benefits of the technology as already indicated by [5]. It is therefore necessary for scientific research to determine the level of education and awareness, public perception and concerns on biotechnology products including GM food in order to identify the key areas of negative myth and misconception and address them in an effective and acceptable way especially for the key food crops.

Maize is the staple food crop in Kenya which plays a great role in food security with the overall consumption estimated at 98-125 kilograms per person per year which translates to about 2700 thousand metric tonnes annually [6,7]. According to [6], maize accounts for 59 and 38% of the staple carbohydrate consumption among 20% of the poorest and richest households, respectively in Kenya and is the dominant staple food among the urban poor. Despite this, the maize demand in the country appears to be outstripping the supply [7]. According to [7], maize production in 2008 was, for instance, about 26 million bags or 2.4 million metric tonnes against a national demand of 34 million bags or 3.1 million tonnes. Similarly, the [8] recently established that the average national maize production in Kenya was 1.56mt/ha in the 2013/2014 cropping year, compared to 9.93mt/ha in the USA for the same year. With the country's population projected to reach 43.1 million bags by 2020, the maize demand in Kenya is likely to rise to 5 million metric tonnes in the near future. Based on these estimates, it is likely that the country could experience a significant maize deficit of up to 1.2 million metric tonnes by 2020 [7].

According to [9], genetic modification (GM) technology can contribute significantly towards the world food security challenges in the world through higher crop yields through the genetic design of hardier and better crop varieties that can withstand drought and disease. The technology might also ensure the production of more nutritional and longer shelf life food crops. According to the International Service for the Acquisition of Agri-biotech Applications (ISAAA), upto 27 transgenic crops are currently cultivated commercially in the world [3]. These crops have been adopted in 28 countries with a record of 181.5 million hectares of GM crops grown in 2014. Some of the leading countries in this line of food production are USA, Brazil, Argentina, India, Canada, China, Paraguay and Pakistan [3]. The leading crops are soybeans, maize, cotton and canola. Transgenic maize is grown commercially by 17 countries which accounts for 30% of the total acreage under maize production in the world [3]. However, although over 20 countries are growing commercial GM crops in the developing world, only 3 countries in Africa are involved, namely, South Africa, Burkina Faso and Sudan (Clive 2014). However, 11 African countries including Kenya are conducting

confined field trials (CFTs) and testing various GM crops.

Currently, there is considerable concern and uncertainty on the impact of biotechnology on both human and environmental health around the world. A lot of negative myth and misinformation exists on the production and consumption of biotech crops especially the GMs. Consequently, many world governments have been extremely careful on the matter. Most governments in the European Union (EU) family of nations have adopted a very critical stand on GM crops and their consumption. Elsewhere, a national survey in Australia found that 89% of respondents believed that genetically engineered tomatoes should be labeled for public awareness [10]. In North America, societies in both the USA and Canada have demonstrated a more acceptive attitude [11]. However, a survey by [12] showed that average consumers in the region are less likely to consume food that is labeled as GM.

In 2000, the Cartagena Protocol on biosafety was launched in order to address the negative impacts of biotechnology on society and environment. The aim of the Protocol was to increase public confidence on biotechnology introductions and product marketing [13]. The Protocol seeks to provide public and private sectors in biotechnology including GM crop production with a commercially valuable legal right to import, introduce, transport, or develop genetically modified organisms (GMOs). The Cartagena Protocol has been subject to considerable controversy especially among the OECD countries particularly between the EU and the USA particularly over the issues of free trade which can create biological insecurity [13]. Consequently, although the USA has been a lead champion on the introduction of GMOs in the world, it has remained a non-party to the protocol just like in the case of the Kyoto Protocol on greenhouse emissions and climate change.

The role of biotechnology in mitigating the runaway maize demand in Kenya might eventually be inevitable in the long run. Currently the Government of Kenya is investing in research, development and capacity building in modern biotechnology with on-going projects on five crops under CFT, namely, cotton, corn, cassava, sorghum and sweet potatoes. However, in order for any alternative food technology to be introduced and successfully adopted in any country, its acceptance by the society is necessary. In this regard, many studies have been undertaken to gauge the level of consumer acceptance for GM foods in the developed countries [14] but such studies are limited in Sub-Saharan Africa [15]. This research gap must be addressed because public confidence is a critical factor in the adoption of biotechnology in the developing countries as emphasized by [16]. It is therefore important to gauge and understand the society's perspective specifically on the application of biotechnology in boosting maize production in Kenya in order to establish the degree of public willingness to embrace this as a solution to the problem of food insecurity. This matter is usually revolving among the upstream experts, technocrats and scientists without adequate participation and consideration of the public views in the downstream. However, if scientists can identify the fears which people have towards biotechnology including GM food products it will then be easier to demystify such concerns using the available scientific evidence.

The specific objectives of this study were therefore to: - a) determine whether the public have any environmental concerns on the implications of GM maize on national biodiversity conservation and biosafety in Kenya, b) assess whether the public have any public health concerns on the introduction of maize related agro biotech, and c) establish whether the public have any religious concerns on the introduction of such production technology.

2. METHODOLOGY

The study was conducted in three areas including:- a) a large scale maize production zone in Moiben within Uasin Gishu County, b) a small scale maize production area in Githunguri within the Kiambu County and c) a maize consumption area in Umoja I urban residential estate in the Nairobi City County. Uasin Gishu County (2,955.3 km^2) is located in the Rift Valley region (34'5''E, 35'3''W; 0'0''S, 0'5''N) with Eldoret as the largest town and also the county's administrative and commercial hub (Fig. 1). The county generally lies between 1,500 and 2,700 m above sea level and shares common borders with Trans Nzoia County to the North, Elgeyo Marakwet County to the East, Baringo County to the South East, Kericho County to the South, Nandi County to the South West and Kakamega County to the North West [17]. The county is one of the key large scale maize growing areas in Kenya with average farm size at 2-10 acres and upto 224,890 acres under maize cultivation. The Uasin Gishu County together with Transnzoia are

considered as the bread-basket of Kenya [17]. The study was restricted to the Moiben Sub-County which located in the northern part of the County (Fig. 1). According to the 2009 national census, christians accounts for 82.9% of the population in Kenya while muslims account for 11.9%. The other religions including traditionalist, hindus, sikhs, and bahais account for the remaining population.

Kiambu County (2,543.5 km^2) is located in the central region of Kenya (1° 10' 0" S, 36° 50' 0" E) and generally lies between 1,200 and 2,500 m above sea level. It borders the Counties of Nairobi and Kajiado to the South, Machakos to the East, Murang'a to the North and North East, Nyandarua to the North West, and Nakuru to the West [18]. The county is one of the high agricultural potential and high population density areas in Kenya with the average farm size below 2 acres. The key crops which are grown in the county include tea, coffee, maize, beans and potatoes. Maize growing in the area is largely for subsistence use. The study was conducted in the Githunguri Sub-County which is a small scale land tenure zone (Fig. 2).

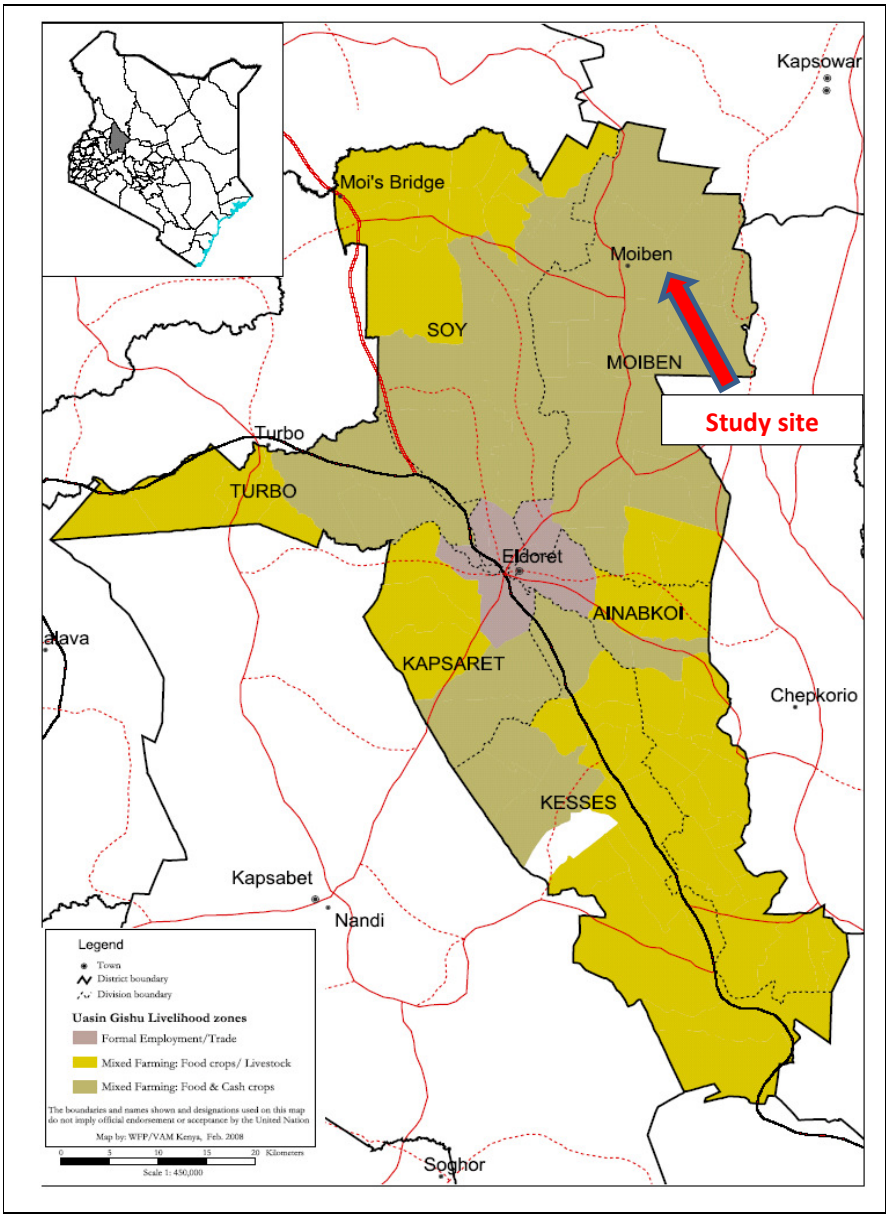

Fig. 1. Map of Uasin Gishu County

Nairobi City County (700 km^2) is located at the edge of the central and rift valley regions of Kenya (1° 17' 31.438" S 36° 49' 19.006" E) and borders Kiambu County to the North and West, Kajiado to the South and Machakos to the East (Nairobi City County 2014). The City of Nairobi lies at an altitude of 1,798 metres above sea level. Maize is the primary staple food in Nairobi in terms of the kilograms consumed per adult equivalent. [6] established that up to 97% of the middle income people in Nairobi used maize related products (maize meal, dry grain or green maize) on regular basis. Nairobi has several sub-counties including Embakasi where the study was undertaken within the Umoja Residential Estate which is a middle income residential area (Fig. 3).

Data collection was undertaken by the use of a semi-structured questionnaire administered through informed adult consent with the household as the basic sampling unit. The standard questionnaire was structured in accordance with the Likert Scale whereby the respondents were offered a choice of five pre-coded responses with the neutral point being neither agree nor disagree [20]. The questionnaire was structured to enable the assessment of the level of public acceptance and public views on maize related biotechnology including GM maize in relation to biodiversity conservation and biosafety, public health and religious ethics. A total of 120 respondents were considered including 30 large scale maize producing households in Moiben, 30 small scale maize producing households in Githunguri and 60 maize consuming households in Umoja. The stratified sampling strategy was used in the identification of households. The identification of target households was done using the framework used during the 2009 national population census with interviews conducted along key roadways by purposely considering every 5th household in the rural areas (Moiben and Githunguri) and every 10th household in the urban area (Umoja). All the data was electronically captures using CSPro software after which it was exported to SPSS version 20 for ease of data cleaning and analysis. The data analysis was undertaken using descriptive statistics means, frequencies, and standard deviation. Inferential statistical analysis was undertaken using the Mann Whitney U test to analyze perception differences between the three household survey clusters, namely large scale maize producers, small scale maize producers and maize consumers.

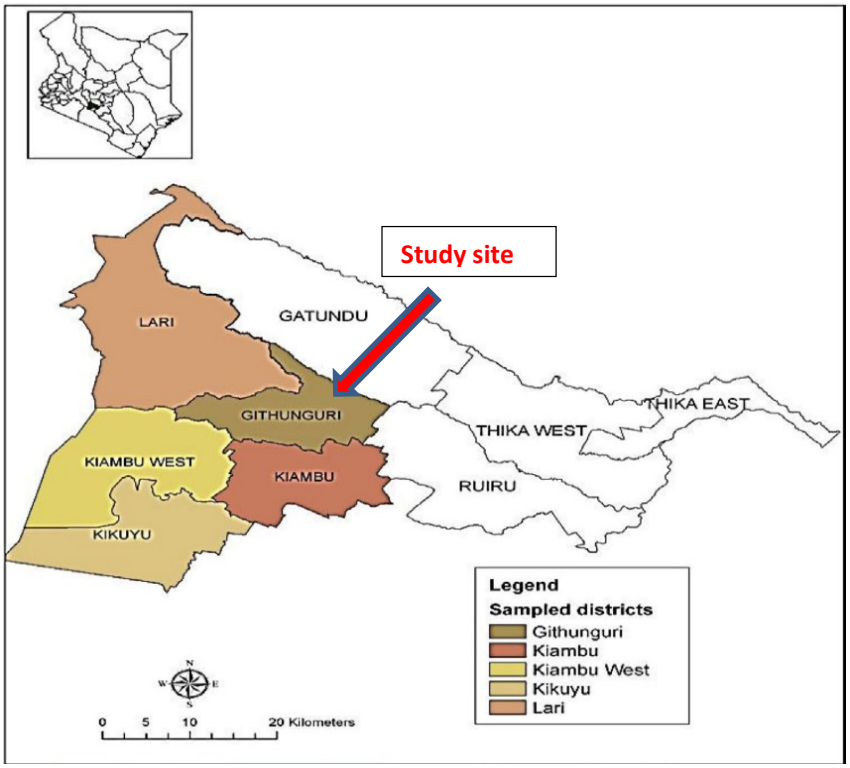

Fig. 2. Map of Kiambu County [19]

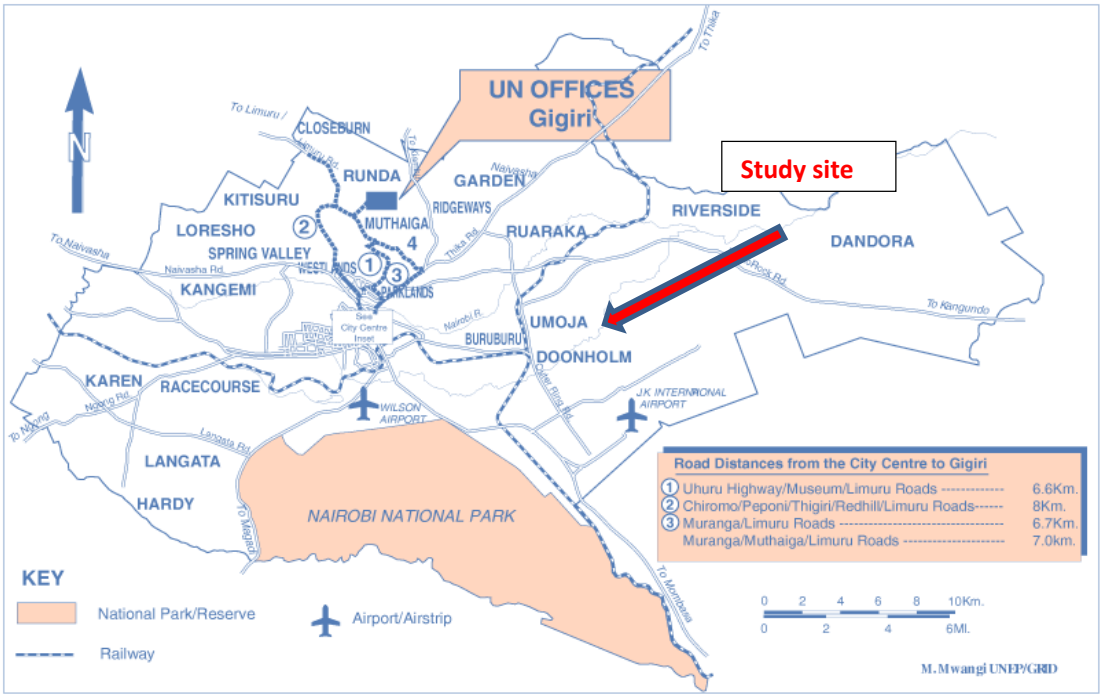

Fig. 3. Map of Nairobi County (UN-Habitat – www. unhabitat.org)

3. RESULTS AND DISCUSSION

Table 1 shows the respondent characteristics in the three study sites. The respondents consisted of 59.2% males and 40.8% females with a higher proportion of aged and less educated respondents in the rural sites and a higher proportion of younger and more educated respondents in the urban site. The difference was probably due to the higher cost of living in the urban area which favours young, energetic and well educated people. In old age, most urban residents in Kenya usually retire and go back to their rural homes where most practice both subsistence and commercial agriculture.

3.1 Biotechnology and Biosafety

The respondents were asked to rank the extent by which they agreed or disagreed on whether the introduction of GM maize in Kenya would affect the environment especially with regard to biodiversity conservation and biosafety. The overall results indicated that 76% of the respondents were worried that the introduction of GM maize would contaminate the conventional

Table 1. General respondent characteristics in the three study sites

		Moiben	Githunguri	Umoja 1
Sample size (n)		**30**	**30**	**60**
Age	18-24	0%	7%	20%
	25-34	7%	20%	45%
	35-44	27%	33%	23%
	45-54	30%	20%	8%
	55-64	13%	13%	3%
	65+	23%	7%	%
Gender	Male	60%	70%	53%
	Female	40%	30%	47%
Level of education	Informal	7%	-	-
	Primary	-	20%	-
	Secondary	40%	60%	25%
	Tertiary	53%	20%	75%

crops through uncontrollable cross-pollination and also cause serious harm to insects in the wild within the farming environments. However, only 37% of the respondents feared that biotechnology would have adverse effects on the wildlife. The findings are shown in Fig. 4.

In terms of the comparative analysis for the three respondent clusters, it was established that up to 83% of the maize consumers, despite their location in urban areas, were worried that the introduction of the GM maize would accidentally invade the entire environment and contaminate conventional maize. This fear was 10-20% higher compared to the 73% and 63%, respectively, of the small scale and large scale farmers, respectively, who had similar concern (Fig. 5). Similarly, 73% of the maize consumers feared that the introduction of GM maize would negatively affect the insects in the environment compared to 63% and 40%, respectively for the large scale and small scale famers. With regard to the potential risk for wildlife, only 40% of both the maize consumers and small scale maize farmers were concerned compared to 27% for the large scale maize farmers (Fig. 5).

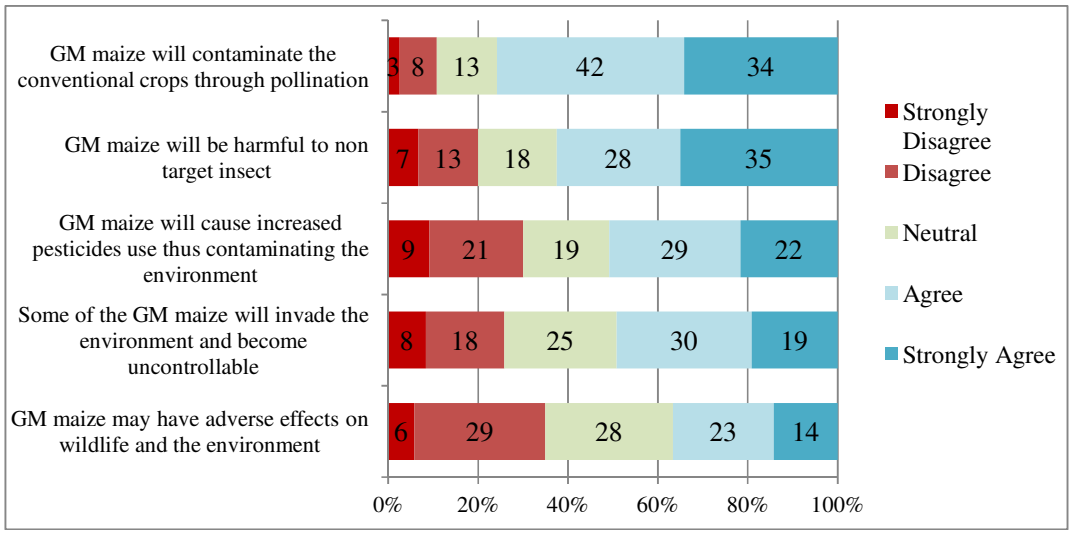

Fig. 4. Public perception on the implications of GM maize on national biodiversity conservation and biosafety

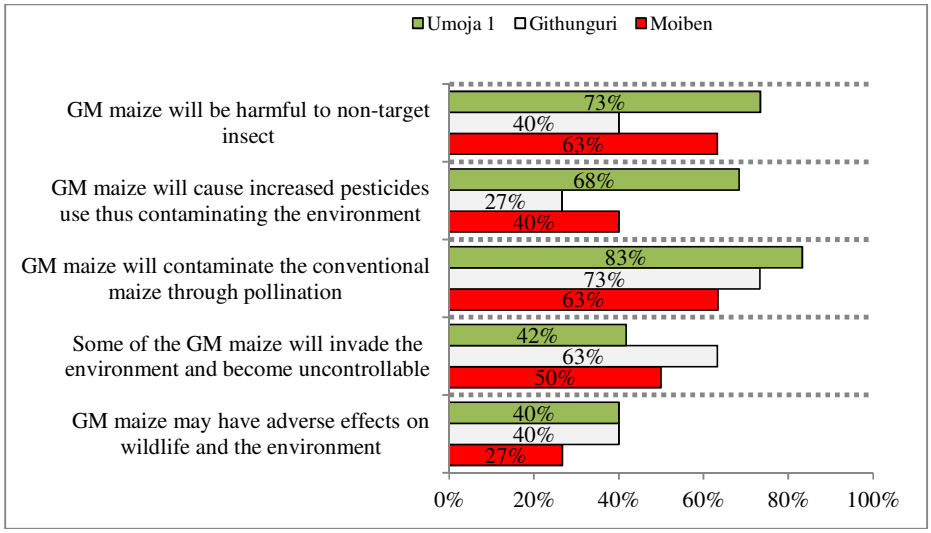

Fig. 5. Comparative analysis on the public perception on the implications of GM maize on national biodiversity conservation and biosafety

Table 2. Mann Whitney U test on perception differences between household groups (small scale farmers, large scale farmers and consumers) on the fact that GM maize may have adverse effects on wildlife and the environment

Test variable 1	Test variable 2	Mann-whitney U	Wilcoxon W	Z	p-value
Small scale farmers	Large scale farmers	442	907	-0.122	0.903
Large scale farmers	Consumers	839.5	1304.5	-0.538	0.591
Small scale farmers	Consumers	843.5	1308.5	-0.497	0.619

The comparative analysis among the three household clusters indicated a higher level of concern on the potential biodiversity conservation and biosafety risks among the maize consumers followed by the small scale maize farmers while the large scale farmers had lower but significant concern. Table 2 above shows the results of the Mann Whitney U test on comparative analysis on the null hypothesis that the introduction of GM maize may have adverse effects on wildlife and the environment. The difference in public perception among the maize growers and maize consumers was not significant (Table 2 above). The test result therefore indicated a unanimous agreement among the society about the common public concern that the introduction of GM maize might have adverse effects on wildlife and the environment.

The public views on the potential risks of biotechnology on biodiversity conservation and biosafety are commensurate with the views of some of the environmental organizations in the world. Over the years, there has been concern, for example, on the coexistence of neighbouring GM and non-GM crops, including organic cultures. This is due to the potential risk of conventional and organic farms getting contaminated with GM traits through cross-pollination by wind and insects from neighboring GM fields or GM seed blown from trucks along nearby roadways. According to the WHO, the consequences of outcrossing can be expected in regions where a GM crop has a sympatric distribution and synchronized flowering period that is highly compatible with a weedy or wild relative species, as demonstrated for rice [21]. Another fear is associated with the likely introduction of Gene Use Restriction Technologies (GuRTs) such as the "Terminator" technologies aimed at creating sterile plants. The Canadian ETC group, for example, has raised concern that the GuRTs would deny farmers in the developing regions their ancient right to save and exchange seeds from previous harvests [22].

The higher level of concern on the potential biodiversity conservation and biosafety risks among the younger and more educated respondents among the urban maize consumers differed from the findings of a similar study in Tanzania [23]. The Tanzania survey showed that the young generation (18-35 years) was more negative to GMOs compared to the older groups. More than 23% of respondents in the young generation visualized GMOs as advantageous while about 32% had a negative opinion [23]. Respondents at advanced age 36-50 years had a positive opinion over the GMOs although the oldest respondents (>50 years) did not support the introduction of GMOs.

3.2 Biotechnology and Public Health

The overall finding in the survey showed that 55% of the respondents in the survey feared that the consumption of GM maize was likely to cause human sickness and death (Fig. 6). Only 32% of the respondents felt that GM maize is reasonably safe for human consumption. Consequently, up to 90% of the respondents indicated the need for the clear labeling in order to allow freedom of choice. However, 50% of the surveyed respondents felt that GM maize could have various benefits, especially in terms of higher nutritional value. The comparative analysis for the three respondent clusters revealed a consensus in terms of the need for the labeling of all foods containing GM ingredients but the desire for this was highest among the maize consumers (93%) followed by the small scale growers (90%) and then the large scale growers (83%) as shown in Fig. 7. Despite this view, 62% of maize consumers believed that GM maize might eventually have higher nutritional value compared to 53% of the small scale maize farming households in Githunguri and 23% for the large scale maize farming households in Moiben.

The comparative analysis among the three household clusters indicated that both the small scale and large growers were skeptical about the safety of GM maize. Table 3 shows the results of

the comparative Mann Whitney U test on the null hypothesis that GM maize might not lead to human sickness and death. The results showed that the difference in public perception was not statistically significant (Table 3). This indicated that there is unanimous agreement among the society about the common public fear that GM maize might lead to human sickness and death.

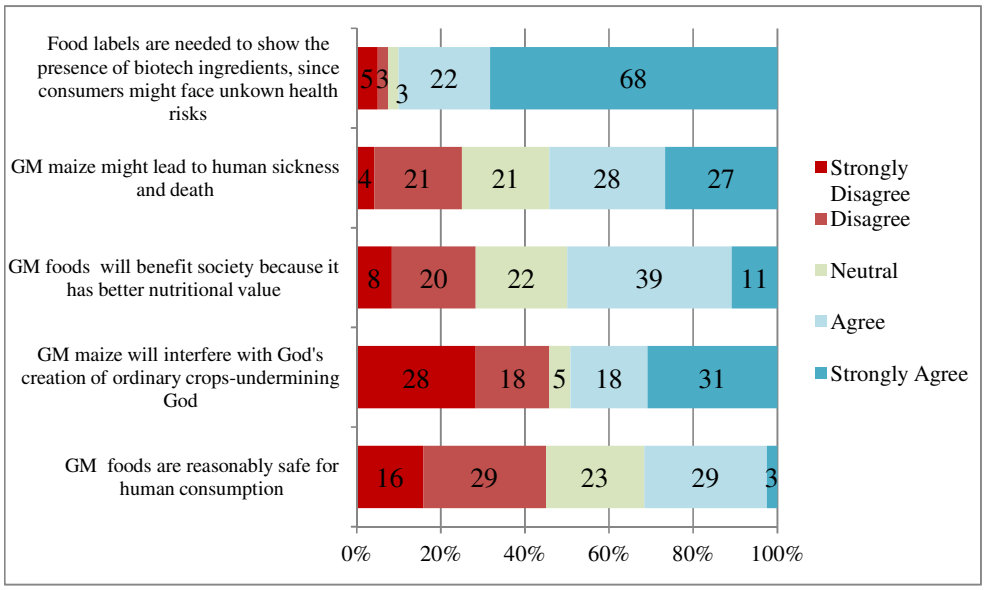

Fig. 6. Perceived concerns on the introduction of GM maize

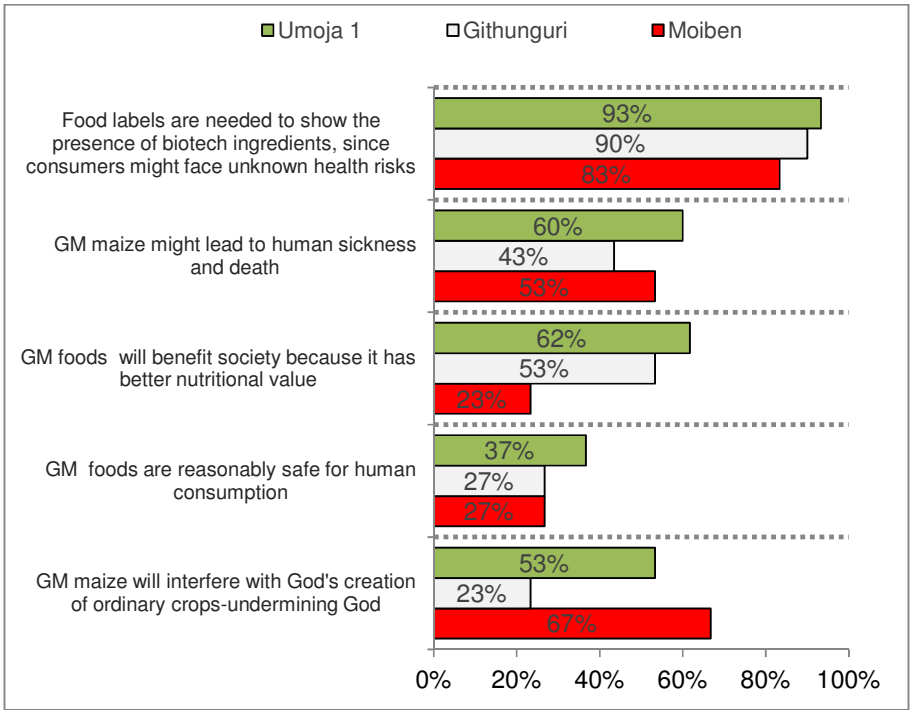

Fig. 7. Comparative analysis of perceived concerns on GM maize

Table 3. Mann Whitney U test on perception differences between groups (small scale farmers, large scale farmers and consumers) on the hypothesis that GM maize might not lead to human sickness and death

Test variable 1	Test variable 2	Mann-whitney U	Wilcoxon W	Z	p-value
Small scale farmers	Large scale farmers	401	866	-0.746	0.456
Large scale farmers	Consumers	770	1235	-1.151	0.25
Small scale farmers	Consumers	716	1181	-1.624	0.104

The findings of the study were similar to the study by [24] on genetically modified bananas in Uganda where a consumer perception survey established a high health risk perception with significant public concern over the likely long-term effects of GM food on health safety. However, the findings of other studies are not similar. A survey conducted by [25], for example, showed that only 28% of the respondents in Turkey had fear that GM foods would pose serious health hazards to consumers with 37% of the respondents indicating that GMOs would not pose any serious health hazard [25]. In the Nordic countries (Denmark, Finland, Norway and Sweden), the proportion of respondents who had serious fear that GM foods are "extremely risky" was 33.7% which was slightly higher than the Turkish respondents [25]. In the USA, up to 53% of the respondents had no fear that GM foods are likely to pose any serious hazard. The desire by up to 93% of the respondents in Kenya that the labeling of GM maize is necessary especially for consumers was similar to the findings of a survey in the USA where a 10-year survey showed that 91% of the respondents indicated that it would be very important to label GM products. In Taiwan, 94% of the respondents required the labeling of GM products before marketing approval was granted [26].

At the moment, no scientific findings have established acute toxic effects in humans or animals as a result of consuming GM products. However, laboratory tests in Russia have recorded negative health effects including death on rats fed on GM soya [27]. One of emerging concerns with GM products is the likely increase in antibiotic resistance because genetic engineers usually include antibiotic resistance genes nearly in every genetic engineered organism [28].

3.3 Biotechnology and Religious Ethics

The findings established that majority of the respondents believed that the introduction of GM maize would interfere with God's creation of ordinary crops thereby undermining God as the Creator of the universe and of all the crops in the world as highlighted in the Holy Bible. Up to 49% of the respondents were concerned about this issue while 46% were not (Fig. 6). The comparative analysis among the three household clusters showed that the large-scale growers in Moiben were the most concerned about the inappropriate religious ethics associated with the introduction of GM maize although they probably stand to be the highest beneficiaries. Up to 67% of the respondents in this cluster, compared to 23% of the respondents in the small scale maize growers' cluster, had a strong opinion that GM maize would interfere with God's creation of ordinary crops thus undermining God. In the case of the maize consumers, 53% of the respondents were similarly concerned about the inappropriate religious ethics associated with the GM technology. Table 4 shows the results of the comparative Mann Whitney U test on the null hypothesis that GM maize that GM maize will not interfere with God's creation of ordinary crops-undermining God. The results indicated that the difference in public perception on this biotechnology concern was significant. This was contrary to the pattern in the other two potential areas of public concerns as explained above and highlighted in Table 2 and Table 3.

Table 4. Mann Whitney U test on perception differences between groups (small scale farmers, large scale farmers and consumers) on the hypothesis that GM maize will not interfere with God's creation of ordinary crops-undermining God

Test variable 1	Test variable 2	Mann-whitney U	Wilcoxon W	Z	p-value
Small scale farmers	Large scale farmers	196.0	661.0	-3.928	0.001
Large scale farmers	Consumers	697.5	2527.5	-1.794	0.073
Small scale farmers	Consumers	549.5	1014.5	-3.113	0.002

It is not clear why there was such a huge difference in public opinion on the introduction of GM maize and religious ethics between the large scale maize farmers and the small scale farmers. However, a similar study was undertaken using a cross section of religions to assess public perception on ethical aspects of biotech rice production in the Klang Valley region of Malaysia established fairly different views. Most of the respondents were not worried about the ethical implications of the transfer of a carrot gene to the modified rice which was considered as religiously acceptable [29]. In the UK, [30] assessed public perceptions of genetically modified food using a national sample of 1,547 respondents aged above 15 years and established that 87% were more concerned about the health risks with only 19% considering religious ethics as an important concern. In comparison, the concerns on human health were higher in the UK compared to Kenya where the respondents had a much higher concern on religious ethics (49%) [31].

4. CONCLUSION AND RECOMMENDATIONS

The findings indicate unanimous public concern among the society about the likely adverse environmental effects of biotechnology including the cultivation of GM maize. The society is worried that the introduction of the GM maize would contaminate the conventional crops through uncontrollable cross-pollination and is also likely to cause serious harm to the insects in the wild. However, there is less concern on the effects of biotechnology on wildlife. Similarly, the findings showed that majority of the people have fear that the consumption of GM maize is likely to cause human sickness and death with unanimous consensus on the need for the labeling of all the food products containing GM ingredients. At the moment, there is no evidence in the scientific domain to proof that the above hazards have occurred in the leading biotechnology nations such as USA, Brazil, Argentina, India, Canada, China, Paraguay and Pakistan. Similarly, there is no scientific evidence of acute toxic effects in humans or animals as a result of consuming GM products except for a few laboratory tests which have indicated negative health effects on rats. The public concerns on the potential negative health impacts of biotechnology and GM food can be considered as mythical fears which are attributed to inadequate awareness, public ignorance and mis-information on biotechnology. This might also stem from inadequate scientific knowledge on the environmental impacts of biotechnology in the world with most of the studies so far having been conducted in the developed world which also controls the technology. On the overall, there is also a strong indication that the introduction of GM maize in Kenya like in other parts of the world could result in some resistance from some religious circles just like other similar controversies such as gay marriage.

On the issue of biotechnology and religious ethics, the results indicate that there is significant difference in public opinion. The difference in public opinion between the large scale maize farmers and the small scale farmers is not clear. However, it might be attributed to the differences in respondent characteristics especially in terms of age and level of education. The large scale household cluster in Moiben was dominated by more aged (45-65+) and less educated respondents who are likely to be more religious compared to the small scale farmers and urban residents in Githunguri and Nairobi.

Based on the findings of this study, it is recommended that, there is need for concerted effort by the government through the National Biosafety Authority (NBA) to ensure adequate public awareness in order to allay public fear and mis-information on biotechnology. Further research is required in the following areas:

a) Contamination of traditional crops through accidental cross fertilization with biotech crops including the identification of the minimum distance for non-cross pollination.
b) Impact of cultivating biotech crops on insect biodiversity.
c) Potential long-term effects of consuming genetically modified foods.

ACKNOWLEDGEMENTS

Many thanks to Ms. Tiffany Mwake at University of Nairobi/Habitat Planners for the kind assistance in data processing. The field support provided by Dennis Kamau, Mercy Kung'u, Joyce Ndunge and Lawrence Odhiambo all from the Centre for Biotechnology at University of Nairobi is also appreciated.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. United Nations, Department of Economic and Social Affairs, Population Division. World Population Prospects: The 2015 Revision, Key Findings and Advance Tables. Working Paper No. ESA/P/WP.241; 2015.
2. Republic of Kenya. Sessional Paper No. 3 of 2012 on Population Policy for National Development, Ministry of State for Planning, National Development and Vision 2030; 2012.
3. Clive J. Global status of commercialized Biotech/GM Crops. ISAAA Brief No. 49. ISAAA: Ithaca, NY; 2014.
4. Kimenju S, De Groote H, Karugia J, Mbogoh S, Poland D. Consumer awareness and attitudes toward GM foods in Kenya. African Journal of Biotechnology. 2005;4(10):1066-1075.
5. Stenholm C, Waggoner D. Public policy in animal biotechnology in the 1990s: Challenges and opportunities. In MacDonald JF, (ed.) Animal Biotechnology: Opportunities and challenges. National Agricultural Biotechnology Report no. 4. Ithaca, NY: National Agricultural Biotechnology Council; 1992.
6. Muyanga TS, Jayne G, Argwings-Kodhek Joshua Ariga. Staple food consumption patterns in urban Kenya: Trends and policy implications. Working paper, Tegemeo Institute of Agricultural Policy and Development, Egerton University; 2004.
7. Nyoro J, Kirimi L, Jayne TS. Competitiveness of Kenyan and Ugandan maize production: Challenges for the future. Working Paper 10, Egerton University, Tegemeo Institute, Nairobi; 2004.
8. Nyoro J, Ayieko M, Muyanga M. The compatibility of trade policy with domestic policy interventions affecting the grains sector in Kenya. Tegemeo Institute, Egerton University; 2007.
9. USDA. 2016 Kenya Corn, Wheat and Rice Report. GIAN Report, Foreign Agricultural Service; 2016.
10. UN Millennium Project. Innovation: Applying knowledge in development. Task Force on Science, Technology, and Innovation. Earthscan, London; 2005.
11. Kelley J. Public perceptions of genetic engineering: Australia, 1994. Working Paper, Department of Industry, Science, and Technology, Commonwealth of Australia; 1995.
12. Stein AJ, Rodriguez-Cerezo E. Low-level presence of new GM crops: An issue on the rise for countries where they lack approval. AgBioForum. 2010;13(2).
13. Rousu M, Huffman WE, Shogren JF, Tegene A. Should the United States regulate mandatory labeling for genetically modified food? Evidence from experimental auctions. RTI International, Experimental Economics Working Paper, January 20; 2003.
14. IUCN. Impacts of GMOs on biodiversity and human health – Information paper, Gland; 2007.
15. Lucht JM. Public acceptance of plant biotechnology and GM crops. Viruses. 2015;7:4254-4281.
16. De Groote H, Overholt W, Ouma JO, Mugo S. Assessing the impact of Bt maize in Kenya using a GIS model. Paper presented at the International Agricultural Economics Conference, Durban; 2003.
17. Cantley M. Democracy and biotechnology: Popular attitudes, information, trust of the public interest. Swiss Biotechnology; 1987.
18. Republic of Kenya. County integrated development plan 2013-2018, Uasin Gichu County; 2013a.
19. Republic of Kenya. County integrated development plan 2013-2017, Kiambu County; 2013b.
20. Omwenga I, Kanja L, Nguta J, Mbaria J, Patrick Irungu. Organochlorine pesticide residues in farmed fish in Machakos and Kiambu counties, Kenya. Cogent Environmental Science. 2016;2:1-9.
21. Joshi A, Kale S, Chandel S, Pal DK. Likert scale: Explored and explained. British Journal of Applied Science & Technology. 2015;7(4):396-403.
22. WHO. Modern food biotechnology, human health and development: An evidence-based study. Food Safety Department, World Health Organization, Geneva; 2005.
23. The Corner House UK. Food? Health? Hope? Genetic Engineering and World Hunger. The Corner House UK, Sturminster Newton; 1999.
24. Republic of Tanzania. Survey of public awareness on biosafety. Vice President's Office, Dar el Salaam; 2012.
25. Kikulwe EM, Wesseler J, Falck-Zepeda J. Attitudes, perceptions, and trust. Insights

from a consumer survey regarding genetically modified banana in Uganda. Appetite. 2011;57:401-413.
26. Basaran P, Kilic B, Soyyigit H, Sengun H. Public perceptions of GMOs in food in Turkey: A pilot survey. Journal of Food, Agriculture & Environment. 2004;2(3&4): 25-28.
27. Hung-Yi S. Taiwan's GM foods labeling legislation - A review. Trends Food Sci. Tech. 2001;12:465-468.
28. Lootens V. Assessment of the technology of genetic modification in light of its socio-economic implications; 2006. Available:http://corescholar.libraries.wright.edu/econ_student/27
29. British Medical Association. The impact of genetic modification on agriculture, food, and health. London, U.K; 1999.
30. Amin L, Azlan NAA, Ahmad J, Ibrahim R. Public perception of the ethical aspects of golden rice in Malaysia. The International Journal of Science in Society. 2011;2(3): 15-34.
31. Poortinga W, Pidgeon NF. Public perceptions of genetically modified food and crops, and the GM nation? Public Debate on the Commercialisation of Agricultural Biotechnology in the UK (Understanding Risk Working Paper 04-01). Norwich: Centre for Environmental Risk; 2004.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/16210