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Assessing knowledge and willingness to use genetically modified crops in Uganda

Abubakar Sadik Mustafa[1], Jamilu E. Ssenku[1], Evelyne B. Nyachwo[2], Grace Cherotich Ruto[2], Nelson Bunani[2], Grace Musimami[3], Ronald Maseruka[4] and Godwin Anywar[1*]

Abstract

Background There has been a lot of debate on genetically modified (GM) crops both globally and locally in Uganda. Whereas some of the debates have been informed by scientific research, many are not. The level of acceptance and attitudes of people towards GM crops is a function of their knowledge. However, there is a paucity of studies on the knowledge and attitudes of Ugandans on GM crops. This study aimed to assess the level of knowledge of GM crops in Uganda.

Methods We carried out a mixed methods study in September 2021 in Bushenyi, Jinja and Wakiso districts. We conducted 18 focus group discussions (FGDs), 13 key informant interviews (KIIs) and 698 quantitative interviews. The quantitative interviews were conducted using structured questionnaires. The FGD and KI interviews were audio recorded and transcribed verbatim. The qualitative data were analyzed using framework analysis and the quantitative data were analyzed using modified Poisson regression to identify factors associated with the level of knowledge of GM crops in STATA 15.

Results Out of the 698 respondents interviewed, only 273 (39.1%) had ever heard of GM crops. About 204 (74.7%) of the 273 respondents reported having a moderate–high understanding of GM crops and 62.3% (170) of the respondents further reported that GM crops are harmful to their health and environment, despite some of their intrinsic benefits, such as high productivity, improved income and resilience to pests and diseases. In addition, Out of the 698 respondents interviewed, only 37.7% were wary of the possibility of the emergence of super pests due to the development of resistance to some GM crops.

Conclusions Most of the community members do not have adequate knowledge about GM crops, hence, there is need for sensitization and legislation on GM crops before their release to the public.

Keywords Knowledge levels, Readiness, Genetically modified organisms, Attitudes, Food security

Background

The world faces an eminent challenge of food safety and security in the coming years [1]. This food security challenge could be addressed through the adoption of genetically modified (GM) crops which are derived from organisms whose genetic material (DNA) has been modified through the insertion of gene(s) from a different organism [2, 3]. The GM crops have been introduced with specific traits that could help farmers in achieving the productivity targets and prevention from various biotic and abiotic stresses and thus have potential to alleviate

*Correspondence:
Godwin Anywar
godwinanywar@gmail.com; godwin.anywar@mak.ac.ug
[1] Department of Plant Sciences, Microbiology & Biotechnology, School of Biosciences, College of Natural Sciences, Makerere University, P. O. Box 7062, Kampala, Uganda
[2] Department of Health Policy Planning and Management, School of Public Health, Makerere University, P. O. Box 7072, Kampala, Uganda
[3] The Farmers Media Uganda, P. O. Box 378, Jinja, Uganda
[4] Institute of Hydrology and Water Resources Management, Leibniz University Hannover, Hannover, Germany

global food insecurity [4]. In the globalized agri-food system of the twenty-first century, plantations of genetically modified crops have increased considerably worldwide, justified by arguments, such as food security and feeding the world's population [5]. Thus, GM crops and foods have generated a lot of debate and stoked controversy in equal measure, in both the public and scientific domains [6, 7]. There are public concerns against GM products, some legitimate and others ill-informed. The GM crops discourse has tended to emphasize the potential harmful effects of GM technology [8]. For example, in studies from other countries by Busscher et al. [9] and Rzymski and Królczyk [10], activists have also argued that genetically modified organisms (GMOs) do not necessarily increase yield [11], but can lead to increased cases of cancer [12]. Such perceived risks of new technologies in the food industry are looked at as threats to consumer health. They are often met with skepticism and resistance because of the many questions surrounding their safety and toxicity, antibiotic resistance, allergies and the nutritional quality of the food [13].

Genetic modification has the potential to solve a myriad of problems currently being experienced in agriculture, hence improving yields and reducing the costs of production [14]. For instance, a meta-analysis by Klümper and Qaim [15] showed that the adoption of GM technology globally caused a reduction in chemical pesticide use by 37%, increased crop yields by 22%, and increased farmer profits by 68%. However, the acceptance and adoption of GMOs on the African continent has been remarkably slow [1]. The low acceptance has been associated with internal factors, such as ineffective or lack of regulatory policies, lack of awareness, misinformation, limited knowledge, and education on the application of such modern biotechnology [1]. In Africa, only South Africa, Burkina Faso, Egypt, and Sudan have commercialized GM crops with South Africa leading in production. Several African countries are at advanced stages of testing GM crops in confined ields which include Burkina Faso, Cameroon, Egypt, Ghana, Kenya, Malawi, Nigeria, South Africa, and Uganda [16].

It has been shown that acceptance of GMOs improves with increase in individual knowledge about GMOs and biotechnology/genetic engineering [17]. The GM foods offer several advantages including increase in food production, increase in resistance to pests, drought tolerance, and beneficial nutrients [18].

The unpredictability of climate change coupled with the burgeoning global population and dire need for affordable and nutritious food [14] have made it imperative to come up with ways of increasing food production. This has called for greater flexibility and innovation in crop resilience and production systems. The use of genetic modification technologies to fill this gap is one of the options that has been embraced by different stakeholders [8, 19, 20]. Unfortunately, the acceptance and adoption of GM crops on the continent has been extremely slow, perhaps due to contrasting views about the benefits and safety concerns associated with them [1]. The lack of understanding and sound knowledge about the GM system is reflected in the formulation of policies and regulatory frameworks for biosafety and their implementation [14]. To date, the GMO bill for Uganda has twice been passed by parliament but not yet signed into a law owing most probably to the limited knowledge about them [21].

Public knowledge and awareness about GMOs plays a major part in the society and affects consumer acceptability and attitude towards them, government regulations, and farmers' adoption of biotechnological products [1]. Several studies have investigated the effects of sociodemographic characteristics, knowledge, and perceived risks and benefits on farmers' attitudes towards GMOs elsewhere [22–24]. The evidence on sociodemographic characteristics is ambiguous [25]. Unfortunately, there are very few studies that have been conducted to assess the level of knowledge on GM crops and factors affecting this knowledge in Uganda. We thus aimed to assess the levels of knowledge of GM crops in Uganda and to highlight the need to conscientize communities about GM technologies to pave way for their easy promotion and commercialization.

Although different African countries such as South Africa, Nigeria, Kenya, and Ethiopia have made some inroads in the development and commercialization of some GM crops, Uganda has largely remained behind. One key factor influencing the adoption of such crops is consumer characteristics and perception. In Uganda for instance Kikulwe et al. [26] demonstrated this to be true with the consumer willingness to purchase GM banana. The country still does not have a biosafety law to guide commercialization of GM crops. The legal environment in generally not enabling in Uganda and the region. There is not much work that has been done to aassess the knowledge and willingness of Ugandans to use GM crops and yet this is one of the bottlenecks to their adoption. Such data would provide much need information to design the best intervention measures.

Materials and methods

Description of the study area

We carried out a cross-sectional study which employed a mixed methods approach. We collected both qualitative and quantitative data. This study was conducted in September 2021 among respondents from the districts of Wakiso in the Central Uganda (0° 5′ N 32° 15′ E and 0° 40′ S 33° 20′E), Jinja in the Eastern Uganda (0° 30′ N 32° 35′ E

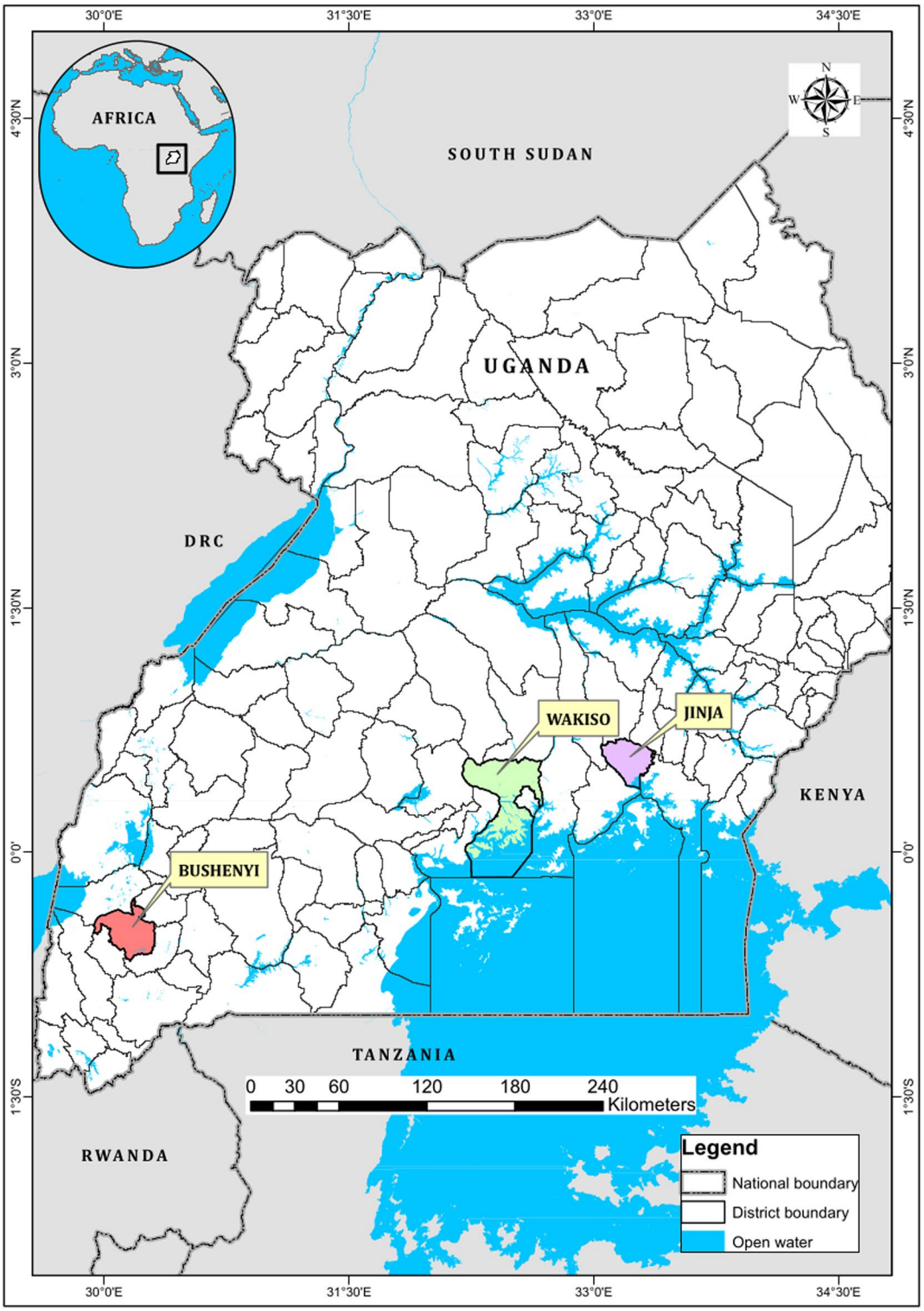

Fig. 1 Study sites in Uganda

and 0° 35′ S 30° 5′ E) and Bushenyi in the Western Uganda (0° 25′ N 33° 5′ E and 0° 25′ S 30° 15′ E) (Fig. 1). The study sites were purposively selected for the following reasons: Bushenyi district is one of the biggest producers of banana commonly known as matooke in Uganda and it is one of the crops that has been genetically modified in Uganda, though not commercially available to the public [27]. Jinja district has a fairly good representation and mix of the local population and tourists, many of whom are foreign. Wakiso hosts the National Agricultural Research Laboratory and has both the urban and rural populations.

The respective sub counties per district were selected using simple random sampling. These sub counties were: Budondo, Busedde, Walukuba-Masese and Buwenge Trading Centre (TC) in Jinja district; Bushenyi-Ishaka TC, Kakanju, Kyeizoba, and Nyabubare in Bushenyi district and Entebbe municipality, Nabweru/Busukuma, Namayumba, and Wakiso TC in Wakiso district (Fig. 1).

Selection of participants

Three main categories of participants for the quantitative data collection were chosen. These were farmers, traders and consumers. Traders were majorly engaged in the selling of agricultural produce in markets. The farmers practiced commercial large-scale farming on more than one acre of land. Consumers were defined as the people who either bought food for consumption or practiced subsistence farming with less than one acre of farmland. All farmers and traders were purposively sampled by selecting participants from their respective associations, while consumers were selected using simple random sampling method.

Data collection

A total of 698 interviews were conducted using a structured questionnaire that was designed in Open Data Kit (ODK) software. These comprised of 142 farmers, 412 consumers, and 144 traders. We also conducted 13 key informant interviews (KIIs) using key informant interview guides and 18 focus group discussions (FGDs). Six FGDs were conducted among farmers, consumers and traders in each of the three districts. All interviews were audio recorded upon receiving prior informed consent from the respondents.

Trained research assistants conducted interviews in the local languages used in study areas. These included; Lusoga in Jinja, Runyankore in Bushenyi and Luganda in Wakiso. However, participants who preferred English were interviewed in English. Data were collected on the level of knowledge of GM crops, factors associated with this level of knowledge and willingness of the participants to use GM crops. COVID-19 standard operating procedures (SOPS) and guidelines by the Ministry of Health were closely adhered to for the face-to-face interviews with close supervision from the study lead persons. These included wearing masks, using sanitizers and social distancing during the interviews. Confidentiality and anonymity of respondents was observed with no names or other respondent identifiers recorded.

Data management and analysis

The quantitative data were downloaded on daily basis from the ODK software and saved as Microsoft excel files. The data files were merged into a single data set which was coded, cleaned and then transferred to STATA version 15 for analysis. Descriptive statistics were used to analyse the socio-demographic characteristics of the respondents. Stratified analysis was carried out to determine the level of knowledge and perceptions of communities towards GM crops across the districts as described in Greenland et al. [28]. The knowledge of the respondents towards GM crops was categorized into; the general knowledge of GM crops, knowledge of the benefits of GM crops and the knowledge of the risks that could result from the use of GM crops. The overall level of knowledge was self-reported and it was categorized into low and high knowledge levels as described by Hwang and Nam [29]. Modified Poisson regression with robust variances was used at bivariable and multivariable analysis to identify factors associated with the level of knowledge of GM crops. Prevalence ratios (PRs) were used to estimate the strength of association between the outcome and indicator variables and associations were tested at a 95% confidence interval (CI). Factors with P value less than 0.05 at multivariate stage were considered significant.

For qualitative data, all the interviews were audio recorded and transcribed verbatim. Interviews that were conducted in local languages, were translated into English and then transcribed [30]. Validated transcripts were read by a team of four people to identify and generate the codes, sub themes and main themes which were entered into a master sheet in excel. The codes were compared and differences were resolved for validity and reliability. Each transcript was double coded. Analysis was done using the thematic content framework analysis and the results were presented in themes [31]. We then systematically applied this framework to each of our transcripts and sifted, charted and sorted material according to the themes [32]. We summarized our results using text and excerpts from the transcripts that elaborately illustrated the meanings or key messages of the findings.

Results

Socio-demographic characteristics of participants

About 35% of the respondents were household heads. The median age of the respondents was 34 (Table 1; Additional file 1:). At least 40.1% (280) of the respondents had attained a secondary level of education, and 65.7% were married. The majority of respondents earned < 5000 UGX a day (about 1.34 USD), and more than half, 54.0% (377) were from urban areas. Close to 70% were subsistence farmers whose main crop was bananas (72.6%).

Table 1 Socio-demographic characteristics of participants (*N* = 698)

Characteristics of respondents	Number	Percentage (%)
Household heads	243	34.8%
Married	447	65.7%
Urban settlement	377	54%
Main crop sold were bananas	352	72.6%
Age > 35 years	348	49.9%
Attained a minimum of secondary education	404	57.9%
Occupation—farmers	181	26.9%
Religion—Christians	477	68.4%
Source of agriculture information—radio	275	39.4
Those that practice any agriculture	486	69.6%

All the 13 key informants interviewed were male district agricultural officers, district production officers and chairpersons of farmers' associations with an average age of 50 years. Most of them had bachelor's degrees in Agriculture. Eighteen FDGs were conducted with an average number of 6 participants per group. The FGDs were composed of women alone, men alone, farmer groups, and consumers.

General knowledge of communities about GM crops stratified by district

Overall, only 273 (39.1%) of the 698 respondents reported that: they had ever heard of GM crops and Jinja had the highest percentage of 45.8% (125 respondents) (Fig. 2). In addition, 204 (74.7%) of the 273 respondents indicated that they had moderate–high understanding of GM crops and expressed the need for more information about GM crops. Out of the 273 respondents that reported they had ever heard of GM crops, 131 (48.0%) had eaten GM crops before, of which 63 respondents (48.1%) were from Wakiso district (Fig. 2). Furthermore, out of the 273 respondents, 237 (86.8%), the main information source for GM crops was the main stream media (radio, TV, and newspapers) (Additional file 2: Table S2). Most of the respondents (170, 62.3%) said that GM crops were harmful to their health and the environment, while 84 respondents (30.8%) considered hybrid crops to be the same as GM

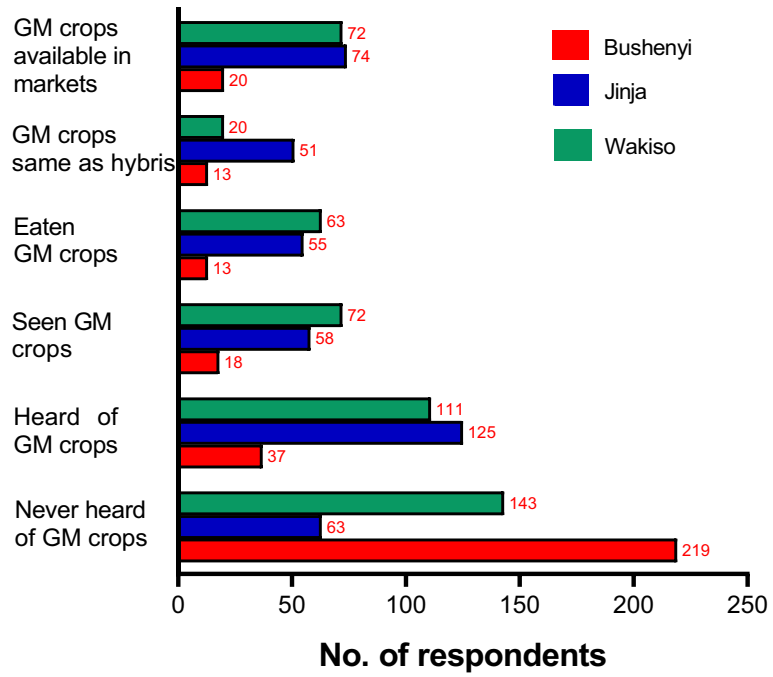

Fig. 2 Level of knowledge on GM crops from participants from the study area

crops (Additional file 2: Table S2). Interestingly, 166 (60.8%) out of the 273 respondents noted that Uganda had GM crops on the market citing banana and maize (Fig. 2, Additional file 2: Table S2).

Among the respondents, 103 (37.7%) were willing to apply gene technology in food production and a similar proportion (39.2%) were willing to grow GM food crops (Fig. 3). it was worth noting that 113 (41.4%) stated that the government was strongly willing to promote GM food crops, and 102 (37.4%) believed that Uganda is strongly willing to embrace GM crops (Fig. 3). The readiness to embrace GM technology was further noted by the fact that majority of the respondents reported that they were willing to buy, eat, sell and grow GM crops (35.9–40.3%) (Fig. 3). This study found that most of the respondents (88.9%) further expressed a need for more information about GM crops. Interestingly, when asked if Uganda should ban GM crops, 70 (25.6%) of the respondents were strongly willing to support a ban on GM crops, while a similar percentage (25.6%) was strongly not willing to support the ban on GM crops (Fig. 3).

In general, key informants and FGD participants reported low knowledge levels among the community members.

"There are few people who know about these crops, it's the truth I want to admit. Even if you conduct a survey, there are very few people that know about it. Even us that know, are not so knowledgeable but at least we know a little. But I want to assure you that very few people know about this topic. The ones who know are few, the number of people who don't know is greater than those who know. Even those of us working in the seeds business, we don't know much about genetically Modified crops, majority of the population are still green in regards to knowing about genetically modified crops" (KI, trader – Wakiso).

We found four key themes under knowledge of GM crops viz; distribution of knowledge, level of knowledge, understanding of GM crops and sources of GM crops.

Knowledge of the benefits of GM crops stratified by district

Most of the respondents 231 (84.6%) believed that GM crops grew faster than non-GM crops (Additional file 3: Table S3) and most of them were from Wakiso district. Most of the respondents 221 (81.0%) reported that the yields of GM crops are higher than the traditional crops. Most of them 105, (84.0%) were from Jinja. Whereas

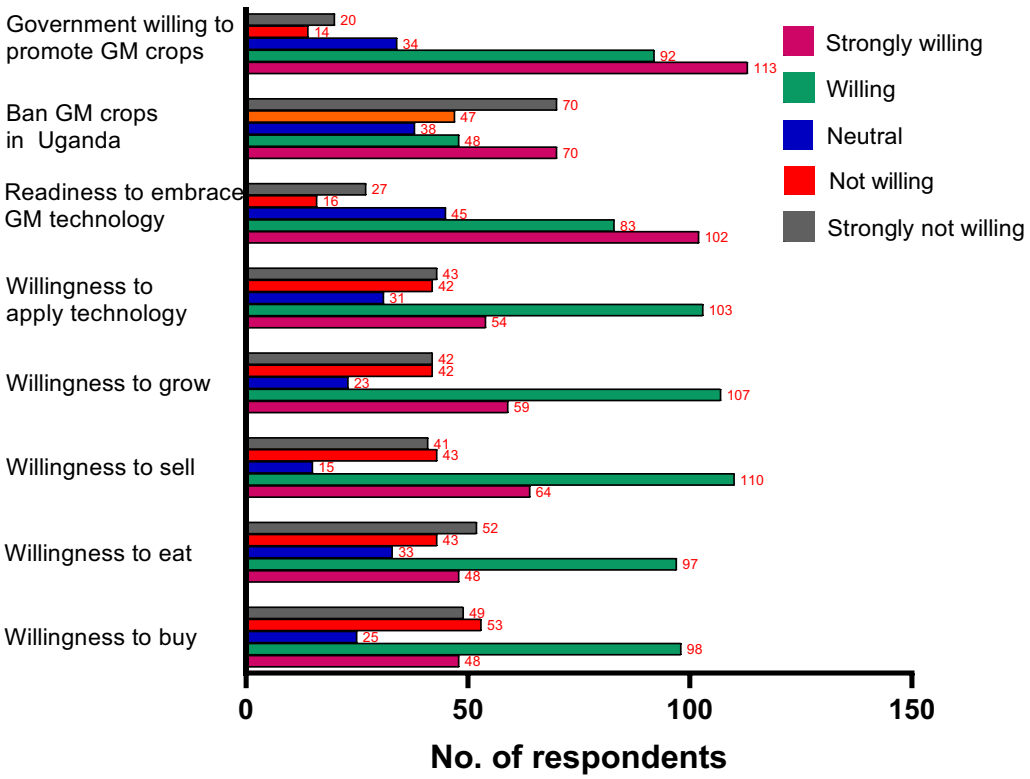

Fig. 3 Assessing the willing of communities in Uganda to use GM crops

most of the respondents noted that GM crops are not as tasty (187, 68.5%), or nutritious (172, 63.0%) as traditional crops, they were more resistant to pests (137, 50.2%). This, therefore, reduces the use of pesticide, making weed and pest management very easy. Another 177 (64.8%) believed that GM crops can eradicate hunger and boost the economy (Additional file 3: Table S3). The respondents reported the benefits of GM crops which we categorized as: financial, crops productivity and resilience and resistance to diseases and pests.

"The benefits would be having crops that are more resistant to crop pests and diseases. Two, we would have high yielding varieties that are highly promoted in the market. Then maybe we would have a long-life span of crops and not having short inter-immediate crops, we would be having long inter immediate crops" (KI 14, Bushenyi)

Most of the participants noted that GM crops have a high productivity due to their fast growing and maturation rates, and high yields. These benefits are key in enhancing food security especially for families and communities with many dependents and small plots of land.

"But what I can think of as a benefit is, it will help people have adequate foods because they don't take long and this will help to fight hunger in many areas/countries. They are all moving towards solving the problem of having shortage of food and agricultural materials given the ever-changing weather conditions" (KI-4, Jinja City)

The financial benefits from GM crops were related to reduced food prices due to bumper harvests and factory jobs as exemplified in the following excerpts.

"These urban farmers don't worry about the seeds; they actually buy without a problem. They don't have many acres of land for farming which is a limiting factor but they use what they have. These crops have high yields and soon there will be a lot of food sold fairly hence families will save on the money spent on food. "It can also lead to job creation, for example if a factory is developing seeds or crops, people can get jobs in such factories" (KI 03-Wakiso)

Participants hailed the GM crops for their resistance to pests and diseases. This attribute enables the GM crops to thrive even in pest and disease infested areas thus the community is able to have food despite these challenges.

"benefits would be having crops which are more resistant to pests and diseases. We have been told of some of those Kawanda (one of the areas where the National Agricultural Research Organization facilities are located) cassava, matooke and potatoes which cannot be affected by these usual diseases and they also can withstand harsh conditions like drought" (KI-10, Wakiso).

Knowledge on the risks of GM crops

About 36.3% of the respondents believed that people who are not allergic to ordinary foods would not be allergic to GM foods either. Most respondents (68.9%), mainly from Wakiso district reported that seeds of GM crops must be bought every planting season making them more expensive to farmers (Additional file 4: Table S4). Furthermore, 103 (37.7%) of the respondents reported that pests may become resistant to pest-resistant GM crops resulting in super pests (Additional file 4: Table S4). Another 45.8% (125) of the respondents reported that it was possible for weeds to acquire herbicide resistant genes from GM herbicide resistant crops and become "super-weeds". About 65% of the respondents reported that growing the same GM foods every season may result into depletion of soil nutrients. Slightly over half (53.9%) reported that GM genes may escape to indigenous crops causing loss to indigenous germplasm (Additional file 4: Table S4). More than three quarters of the respondents believed that scientists know everything about the long-term impact of GM foods.

Participants expressed limited knowledge on the harmful effects of GM crops. The commonest risks reported were harmful effects to health, and depletion of soil fertility. GM crops were thought to be responsible for diseases such as cancers which was attributed to the spraying and the technology used to modify the crop varieties.

"I personally got worried about it, and thought that such crops can be harmful to our health and can make us develop diseases we have never heard about, I got scared, truthfully, I got scared and I thought those things that are modified can bring diseases, unless if we get enough sensitizations and explanations from scientist regarding the safety of GMO crops to our health, and their benefits. In these times we are worried about those genetically modified seeds and I'm completely scared of them" (KI-10, Wakiso)

However, most of the respondents argued that GM crops cannot cause soil degradation but rather loss of soil fertility. This could be is attributed to many other factors such as over tilling of the land.

"Soil degradation, naturally most of the soil has degraded and most of the nutrients are used up. We can't say that GMO's have deprived the soil but under the GM technology there are genes they can

use to mine the toxins out of the soil. Issues like heavy metal contaminants produced by factories, these can be mined from the environment and this would make the soil much better." (KII - 3).

The financial burden associated with the cost of growing and purchasing GM crops is mainly through the purchase of planting material which cannot be regrown, whereas the other costs are directed towards the purchase of pesticides.

"You talked about the cost of production, with exception of the cost of the seed. This comes back to the side of business, if the cost of the seed is high but with minimal losses. Personally, I think it's ok because we all invest in something that will give us high yields! (KI-0 3, Wakiso District)
"Another disadvantage is GM crops require much attention, such as application of fertilizers and spraying is a must. Most of the farmers here don't have money to invest in pest and disease management. Another disadvantage is if you plant National Agricultural Research Organization (NARO) [a GM crop] matooke next to original matooke, the original will die so we don't know what the problem is. I think because GM grows fast utilizing all the nutrients in the soil which leaves the original malnourished" (FGD-09, Consumers-Wakiso district)

Distribution of knowledge on GM crops

The knowledge on GM crop varied by age group, education status, occupation and exposure. Some of the FGDs showed that the youths and women were more knowledgeable about GM crops, because they were more involved in farming than other groups.

"Women welcome them (GM crops) more than anyone else but they do it without knowledge on how they should be handled and they end up not getting much. In most cases it's the youth and women because they are the ones who are always in the gardens and get to know about these new crops." (FGD15, Consumers, Bushenyi).

Some of the FGD participants also highlighted that the youths were more knowledgeable about GM crops, because they are more interested in high yields and were not as exposed to the local indigenous varieties of food crops as the elders.

"They are the youths because the local varieties we are talking about they have never eaten, and because they are growing up in this era of GM crops, it's also because they are accustomed to big and nice-looking foods". (FGD-13, Traders Jinja).

Most of the key informants noted that the educated and those exposed to agricultural trainings were more informed about GM crops than the rest of the population, since they have more opportunities and access to information. However, all key informants were dissatisfied with the level of knowledge on GM crops that they have due to lack of trainings and sensitization.

Level of knowledge on GM crops

Under this theme, three subthemes were derived. These were: not knowledgeable, quite knowledgeable, and very knowledgeable about GM crops. The community especially farmers and consumers reported that they were quite knowledgeable about GM crops, while the traders were more knowledgeable. Most of the key informants mentioned that they had ever heard about GM crops, but they were not well-informed about them. This was emphasized in expressions of limited knowledge, since they had never received any training on GM crops. Most of the participants in the FGDs from Wakiso reported that they were quite knowledgeable about GM crops and the least knowledgeable were from Bushenyi district.

Difference between genetically modified crops and the hybrids

Although it is not possible to visually distinguish GM from non-GM crops, many of the participants and even key informants described hybrids as GM crops.

"Yes we see some improved breeds but me as a person I cannot differentiate between modified hybrids for example from a GMO" (KI 2, Bushenyi)

Sources of information and knowledge on GM crops

Most of the participants mentioned the relevance of radio talks shows or programs in sensitizing them about GM crops. Some of the key informants attributed their knowledge to the various training opportunities through farmers' associations.

"Media can help through radio talk shows but also brochures should be made and distributed among the farmers associations. These associations have access to the farmers. These farmers will take it home, read it over and over again may be the farmer will finally appreciate. Some areas are hard to reach and farmers have no radios. Timing the radio show when the farmer is back home might be a challenge and some places have difficulty with networks and signal" (KI 17, Bushenyi)"

Factors associated with individual knowledge towards GM crops

Being between the age of 35–44 years, not attending school, and occupation were significantly associated with knowledge towards GM crops (Table 2). Respondents between 35 and 44 years were 2.65 more likely to be knowledgeable about GM crops than those who were below 24 years (APR 2.65, 95% CI 1.13–6.22). Respondents who were not attending school had a 0.47 less likely to be knowledgeable about GM crops compared to those who were in school (APR 0.47, 95%CI 0.24–0.91).

Among the factors associated with knowledge of GM crops, five themes were identified and viz: financial, socio-cultural, education level, existing policies, and climate change. Financial factors were reported to be a barrier to the acquisition of knowledge on GM crops. This is because of the limited financial resources to facilitate trainings, sensitization workshops and demonstrations on GM crops in communities leaving many people uninformed about them. There are limited resources to facilitate research and the necessary laboratory activities that are in generating knowledge on GM crops.

> *"The Ministry of Agriculture has not been funded much to the extent that there are not enough extension workers. I don't know if they don't get enough and yet they are crucial like doctors. So, the government should fund agriculture to help in subsidizing agro-input supplies like pesticides, to make access easy for people." (FGD 6, Jinja)*
> *"I am willing to grow the GMO crops but the cost of production is high. So, if I get the seeds, pesticides I am willing to grow them." (FGD 4, Jinja)*

Education level and trainings: educated individuals are likely to be more knowledgeable about GM crops use because of more exposure than their uneducated counterparts. However, the participants also reported that the trainings and sensitization sessions on GM crops contributed to their knowledge on GM crops.

> *"Actually, there is no one who knows about GMOs, though you chose this Bushenyi with a presumption that people are well informed, but people don't know even when you go asking these extension workers the way we talk about them is different. I think these are perception issues because: first we don't have enough knowledge regarding GMOs because we are neither trained or well exposed even if we went to school and studied agriculture" (KI 3, Bushenyi)*

Socio-cultural factors

Most of the participants mentioned that they were more attached to the indigenous crop varieties which they found tastier than the GM crops. This has created a bias towards GM crops and the community is not willing to acquire more knowledge on them.

> *"But for the consumers and farmers it has been controversial. The public doesn't trust these genetically modified crops so they are very skeptical when you talk about GM. They prefer the traditional or original seeds and they struggle to get our original food because we want to enjoy food." (KI 5, Jinja)*

Existing policies on GM crops

With no known existing laws to govern GM crops, the policy does not allow for GM crops to be grown in the communities. This has affected the level of knowledge on GM crops.

> *"The policy doesn't allow us to feed the people to test the product. So how can they take up the technology yet even feeding is a challenge because it has associated ethical issues." (KII). "This means there is a gap either in communication or in presentation. Caution should be taken, there should not be any rushing but also there should be rationalism" (KI 3, Wakiso)*
> *"The truth is that, I have heard about a policy/law that was intended to block modified seedlings into the country but am not sure if the government through the parliament signed that bill" (KI 8, Wakiso)*

Climate change

Most of the respondents reported that climate change has indirectly been a driving force towards the generation of knowledge on GM crops, since these crops can be modified to adapt to specific climates and weather conditions.

> *"I think moving forward because so many changes have taken place in terms of nature, let's talk about climate change, farmers begin the season when rains come, they plant their maize and within one month the rains disappear and crops are destroyed. My final remark is that GM crops are the way to go. Given the change of things, there is population increase, land is stagnant/scarce there is no way you can avoid GM crops and climate change The way population is increasing and they need to feed but climate wont allow food to grow; so the faster we learn about and embrace GM Crops, the better for*

Table 2 Factors associated with individual knowledge towards GM crops

Variable	*N* (%)	Knowledge about GM crops		*P* value	UPRR (95% CI)	*P* value	PRR (95% CI)	*P* value
		Low (%)	High (%)					
Household head								
Yes	176 (64.5)	121 (64.0)	55 (65.5)		1			
No	97 (35.5)	68 (36.0)	29 (34.5)	0.817	0.96 (0.66–1.39)	0.818		
Relationship with household head (*N* = 242)								
Wife/husband	64 (66.7)	45 (67.2)	19 (65.5)		1			
Daughter/son	24 (25.0)	15 (22.4)	9 (31.0)		1.26 (0.66–2.40)	0.476		
Mother/father	8 (8.3)	7 (10.5)	1 (3.5)	0.406	0.42 (0.64–2.76)	0.368		
Respondent age (*N* = 698)								
≤ 24	37 (13.6)	27 (14.3)	10 (11.9)		1		1	
25–34	91 (33.3)	61 (32.3)	30 (35.7)		1.22 (0.67–2.24)	0.521	2.51 (1.01–6.21)	0.047
35–44	68 (24.9)	41 (21.7)	27 (32.1)		1.47 (0.80–2.69)	0.214	2.65 (1.13–6.22)	0.025
≥ 45	77 (28.2)	60 (31.8)	17 (20.2)	0.126	0.82 (0.42–1.61)	0.558	1.69 (0.62–4.60)	0.303
Education level								
No education	16 (5.9)	9 (4.8)	7 (8.3)		1			
Primary	76 (27.8)	59 (31.2)	17 (20.2)		0.51 (0.25–1.03)	0.059		
Secondary	118 (43.2)	81 (42.9)	37 (44.0)		0.72 (0.39–1.33)	0.290		
Tertiary	63 (23.1)	40 (21.2)	23 (27.4)	0.189	0.83 (0.44–1.59)	0.583		
Attending school								
Yes	26 (9.5)	17 (9.0)	9 (10.7)		1		1	
No	247 (90.5)	172 (91.0)	75 (89.3)	0.655	0.88 (0.50–1.54)	0.648	0.47 (0.24–0.91)	0.025
Marital status								
Single	56 (20.8)	39 (21.0)	17 (20.5)		1			
Married	187 (69.5)	131 (70.4)	56 (67.5)		0.99 (0.63–1.55)	0.953		
Divorced/separated	15 (5.6)	9 (4.8)	6 (7.2)		1.32 (0.63–2.75)	0.463		
Widow/widower	11 (4.1)	7 (3.8)	4 (4.8)	0.844	1.20 (0.50–2.88)	0.687		
Occupation								
Farmer	72 (26.4)	57 (30.2)	15 (17.9)		1		1	
Salaried employment	36 (13.2)	22 (11.6)	14 (16.7)		1.87 (1.01–3.43)	0.045	1.67 (0.73–3.81)	0.225
Petty trader	80 (29.3)	57 (30.2)	23 (27.4)		1.38 (0.78–2.44)	0.267	1.22 (0.59–2.51)	0.597
Casual laborer	20 (7.3)	11 (5.8)	9 (10.7)		2.16 (1.11–4.19)	0.023	2.08 (0.85–5.12)	0.110
Domestic activities	32 (11.7)	25 (13.2)	7 (8.3)		1.05 (0.47–2.33)	0.904	1.35 (0.50–3.65)	0.549
Others	33 (12.1)	17 (9.0)	16 (19.1)	0.028	2.33 (1.31–4.13)	0.004	2.32 (1.15–4.70)	0.019
Money earned per day								
< 5000/=	65 (23.8)	44 (23.3)	21 (25.0)		1			
> 5,000/=	182 (66.7)	126 (66.7)	56 (66.7)		0.95 (0.63–1.44)	0.818		
Nothing	26 (9.5)	19 (10.1)	7 (8.3)	0.881	0.83 (0.40–1.72)	0.622		
Religion								
Catholic	83 (30.4)	56 (29.6)	27 (32.1)		1			
Protestant	93 (34.1)	66 (34.9)	27 (32.1)		0.89 (0.57–1.39)	0.616		
Muslim	53 (19.4)	39 (20.6)	14 (16.7)		0.81 (0.47–1.40)	0.455		
Others	44 (16.1)	28 (14.8)	16 (19.1)	0.712	1.12 (0.68–1.84)	0.662		
Residence (*N* = 698)								
Rural	122 (44.7)	94 (49.7)	28 (33.3)		1		1	
Urban	151 (55.3)	95 (50.3)	56 (66.7)	0.012	1.62 (1.10–2.38)	0.015	1.09 (0.68–1.76)	0.722
Source of agricultural information (*N* = 698)								
Radio	91 (33.3)	65 (34.4)	26 (31.0)		1			
Television	71 (26.0)	47 (24.9)	24 (28.6)		1.18 (0.75–1.88)	0.474		

Table 2 (continued)

Variable	*N* (%)	Knowledge about GM crops		*P* value	UPRR (95% CI)	*P* value	PRR (95% CI)	*P* value
		Low (%)	High (%)					
Farmers association	27 (9.9)	16 (8.5)	11 (13.1)		1.43 (0.81–2.50)	0.214		
None	17 (6.2)	14 (24.9)	3 (3.6)		0.62 (0.21–1.82)	0.381		
Others	67 (24.5)	47 (24.9)	20 (23.8)	0.529	1.04 (0.64–1.71)	0.861		
Practice any agriculture (*N* = 698)								
Yes	188 (68.9)	135 (71.4)	53 (63.1)		1			
No	85 (31.1)	54 (28.6)	31 (36.9)	0.170	1.29 (0.90–1.86)	0.164		
Crops grown (*N* = 485)								
Banana	52 (27.8)	35 (26.1)	17 (32.1)		1		1	
Maize	56 (30.0)	44 (32.8)	12 (22.6)		0.66 (0.35–1.24)	0.194	0.85 (0.45–1.60)	0.606
Cassava	45 (24.1)	32 (23.9)	13 (24.5)		0.88 (0.48–1.62)	0.688	0.96 (0.51–1.78)	0.887
Others	34 (18.2)	23 (17.2)	11 (20.8)	0.556	0.99 (0.53–1.85)	0.974	1.07 (0.55–2.09)	0.840
Crops sold								
Banana	132 (70.6)	93 (69.4)	39 (73.6)		1			
Maize	39 (20.9)	32 (23.9)	7 (13.2)		0.61 (0.29–1.25)	0.177		
Cassava	10 (5.4)	7 (5.2)	3 (5.7)		1.02 (0.38–2.71)	0.976		
Others	6 (3.2)	2 (1.5)	4 (7.6)	0.089	2.26 (1.21–4.22)	0.011		

us before we run into trouble of people dying because of famine" (KI 9, Bushenyi)

Link between knowledge on GM crops and willingness to use GM crops

Eight out of 13 key informants reported that the lack of willingness to use GM crops was attributed to the limited knowledge among the expected users. This has led to the poor attitude towards GM crops, because there are several myths about them. Some key informants also expressed the fear of communities to consuming GM crops, because they are not aware of the expected side effects or outcomes. They attributed this to the limited knowledge on GM crops and poor training. Most of the FGD participants mentioned that lack of knowledge on GM crops limits their willingness to use them.

"So, I think the willingness depends on the thorough explanation that these things are safe and understood, so we would be willing to use them and like I said earlier, looking at their quality, their taste, if those things are addressed we would be willing to use them and of course at the community level, farm level, like I said these people are looking at increasing their production and productivity. So, they would be willing if all the other things are explained" (KII-AA, Bushenyi)

"If they come out and tell us about the good things and bad things about genetically modified crops we shall then embrace them but if we don't get enough explanations/sensitization we shall remain unaware" (KI-12, Wakiso)

The respondents also mentioned that it is costly to grow GM crops, since there is need to buy inputs at the start of every season. Farmers will have to spend a lot of money on purchasing pesticides to spray the crops:

"However, the rural farmers will want to save seed from previous season to the next season. They have great challenges of affordability of seeds. The rural farmers don't like GM because of buying seed expensively every season" (KI 5, Jinja)

Discussion

Consumer attitudes towards GM food are complex and interwoven with the consumer's knowledge of the science, culture, lifestyle and public perception [6]. Education plays an important role in how GM crops are perceived. This can play an important role in their adoption. Sörqvist et al. [33] reported that consumers who lack education and proper knowledge on GM foods are likely to have a distorted perspective on them.

A survey on consumers' perception of GMOs in Korea indicated those consumers with higher levels of education, income, and food involvement and more exposure to negative information about GM foods tended to overestimate their actual knowledge level [29]. They also noted that consumers with less education and higher income were more likely to underestimate their knowledge on GM crops. In addition, people who over estimate

their knowledge on GM crops have higher risk perception, lower benefit perception, and lower intention to purchase GM foods than their counterparts [29].

The observation by most respondents that GM crops were more resistant to pests, therefore, reducing the use of pesticide, and making weed and pest management easier has been scientifically proven. Klümper and Qaim [15] reported that on average, GM technology adoption has reduced chemical pesticide use by 37%, increased crop yields by 22%, and increased farmer profits by 68%. Yield gains and pesticide reductions are larger for insect-resistant crops than for herbicide-tolerant crops. Yield and profit gains are higher in developing countries than in developed countries.

A bibliometric analysis on consumer perception and preference of GM foods by Sendhil et al. [34] indicated that positive responses to GM foods by consumers is influenced by the governments response of either banning or approving them. Since the government of Uganda has not approved the use of GM crops, this could partly explain the generally negative perception towards them.

In addition, it has been shown that the general public support for GM crops increases when the potential benefits are clearly communicated to the users in a simple non-technical language by well-regarded scientists [34]. The largely negative perception and attitude towards GM crops in Uganda can partly be attributed to this and is evident from the fact that some of the respondents had never heard about GM crops. Similarly, low levels of knowledge of GMOs have been reported in Zimbabwe [35].

The risk perceptions of consumers towards GM foods are significantly affected by their age, gender, and education [36]. The negative perception about GM crops is also attributed to their taste. Most of the respondents did not consider GM crops to be tasty as non-GM crops. Taste is considered an important factor, because it is a strong determinant of consumer choice as shown with the GM banana in Uganda [26].

GM skepticism is not new and is generally prevalent across Africa. Similar concerns raised in this study have been raised in other parts of the Africa, such as Kenya, and Nigeria, where issues such as environmental, human, and animal health safety and ethical issues have been highlighted [37, 38].

In addition, the skepticism is fueled by perception that GM crops are expensive, because the farmers must rely on the seed companies for their supplies. This makes acquisition of the material expensive but is also starkly different from the culture of keeping seed for the next plant season from the previous one.

It is, however, known that GM crops have numerous potential risks associated with their consumption. These include both known and unknown health-related risks, such as antibiotic resistance, and allergies. Other risks may be environmental affecting nontarget organisms, pollination-related issues, and the emergence of resistance to insecticides [3]. It is important to note, however, that the potential risks, however, do not always translate into perceived risks by consumers [36].

Although this study used a mixed methods approach to collect data which gave it more rigor and validity, it did not focus on key crops but remained open to gather general opinion from respondents and the information collected from the respondents was highly subjective.

Conclusions

Most of the respondents reported that they had low knowledge levels on GM crops. They also believed that GM crops were harmful to both human health and posed threats to the environment despite their reported benefits. It emerged from some of the focus groups discussions that the youths and women were more knowledgeable about GM crops, because they were more involved in farming. There is need to sensitize the community about GM crops and use of demonstration gardens was highly recommended. With no law currently in place to control the use of GM crops on the market, there is need to pass a law on GM crops before the roll out and release of GM crops to the public.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40066-023-00434-4.

Additional file 1: Table S1. Socio-demographic characteristics of participants (N =698).

Additional file 2: Table S2. General knowledge of the respondents about genetically modified crops, stratified by district.

Additional file 3: Table S3. Benefit knowledge assessment of the respondents about GM crops, stratified by district.

Additional file 4: Table S4. Risk knowledge assessment of the respondents about GM crops, stratified by district.

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Author contributions

SMA led the study conceptualization, design, tools development, data collection, analysis and manuscript writing. EBN, GRC and NB contributed to the protocol development, tools development, data collection. GM, RM, JES & GA contributed to analysis and manuscript writing. All authors contributed towards drafting the final manuscript.

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Availability of data and materials
The data sets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Ethical approval was obtained from the Makerere University Social Sciences Research Ethics Committee (MUSSS-2021-41) and the Uganda National Council of Science and Technology (UNCST), (SS738ES). Preceding data collection, administrative clearance was granted by the district administrative structures and consent was sought from the study participants. All data obtained were treated as confidential and anonymous and identifiers were used. We restricted data access to only the investigators and the analysis team.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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