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Potential benefits of genetic modification (GM) technology for food security and health improvement in West Africa: Assessing the perception of farmers in Ghana and Nigeria

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We assessed the perception of farmers towards potential adoption of genetic modification (GM) technology for improving health, food security and agricultural productivity using a semi-structured interview. A total sample of 54 small-scale farmers participated in 6 focus group meetings (FGMs) and 23 in-depth interviews at six locations in Ghana and Nigeria (West Africa). Our results reveal that most farmers have a very poor understanding of GM technology which they often misunderstood as traditional plant breeding biotechnology. While most respondents focused on the potential benefits of GM technology including high-yielding varieties, better nutritional value and shorter growing cycle crop traits, only a few respondents were concerned about the potential health and environmental risks of GM technology. Root and tuber crops such as cassava, yam and sweet potato were mostly discussed for health improvement and food security through GM technology. This study emphasizes the need to recognize challenges such as lack of awareness, inadequate training, low level of education and poor extension services among others in introducing new technology including GM technology to resource-poor farmers in African countries like Ghana and Nigeria. We conclude that failure to address these challenges will impede the adoption of GM technology. Therefore, Ghanaian and Nigerian government(s) must put in place policy measures to address these problems.

Key words: Food security, health improvement, genetic modification (GM) technology, Ghana, Nigeria, West Africa farmers.

INTRODUCTION

The issues of food insecurity and malnutrition are topics of hot debate in developing countries, particularly countries in sub-Saharan Africa. Food insecurity is a product of low agricultural productivity, post-harvest losses and poor facilities that affect many parts of Africa (FAO, 2009). Malnutrition is a direct product of food insecurity.

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Abbreviations: GM, Genetic modification; **R and D,** research and development; **FGMs,** focus group meetings.

A large number of people suffer from deficiencies of micronutrients such as minerals, iron and vitamin A with devastating effects on population including high mortality and morbidity rates, blindness, mental retardation among the children, agricultural labour reduction, and low quality of life. According to FAO, about 200 million people are malnourished in Africa mostly young children under five years of age partly due to rapid decline in agricultural productivity. Improving food security at national and household level is fundamental to reducing hunger and malnutrition in Africa (FAO, 2010; Pinstrup-Andersen, 2009).

The advanced technology such as modern biotechnology has great potential to increase yields and to improve agricultural productivity. One example of modern biotechnology is genetic modification (GM) technology which has been touted as part of solutions to many of the woes afflicting agriculture in Africa. Only GM crops such as maize, cotton, soybeans and canola have been commercialized around the world including countries in Africa since 1996. To date, only four African countries such as Burkina Faso, Egypt, Sudan and South Africa are commercially producing GM crops despite steady growth of GM crops around the world (James, 2013). Limited adoption of GM crops in Africa is partly due to controversy surrounding the adoption of GM technology, particularly with regards to environmental and health risks. For example, recent ban of GM foods and products in Kenya was due to a controversial study that showed that rats fed with GM maize developed cancerous tumours (Nordling, 2012), although this study was later withdrawn due to a serious concern regarding the data.

No GM staple crop is yet to be commercialized or released to the farmers in developing countries including countries in Africa as most research and development (R and D) programs from multinational cooperation have largely focused on cash crops. However, some African countries have ongoing R and D on greenhouse laboratory experiment and field trials. For example, GM biofortified cassava, GM biofortfified sorghum and GM maruka resistant cowpea field trials have been ongoing in Nigeria since 2009. Apart from GM cotton and GM maruka resistant cowpea that started early September 2013 in Northern Ghana, sweet potato is one of the crops that has been recently approved by the Ghanaian government for field trial.

Farmers' opinions are important as they are some of the key stakeholders in decision-making to facilitate adoption and diffusion of new innovation (for example, GM technology). Farmers' knowledge about a particular innovation is fundamental to decision making process and its ultimate adoption (Kaup, 2008; Smale and De Groote, 2003). A growing body of literature (Finger et al., 2009; Kolady and Lesser, 2005; Krishna and Qaim, 2007; Kruger et al., 2011) has examined farmers' attitudes toward the adoption of GM technology in developing countries. For example, a study by Finger et al. (2009) showed that cost reduction potential and easier crop managements were part of the reasons that would encourage farmers to accept GM crops in Argentina. Chong (2005) found out that farmers in India would accept GM crops if it could lead to economic benefits with little or no concerns about the risks associated with the GM technology. Given little or no study on farmers' perception of GM technology in Africa, this study is probably the first to assess the attitude of farmers toward GM technology in West Africa.

MATERIALS AND METHODS

Study location

The research was conducted among small-scale farmers in six different locations in West Africa (Ghana and Nigeria), in January 2011. Three locations in Ghana; Fianso, Cheyohi, and Hodzo are designated as A, B and C, respectively and three locations in Nigeria; Oko Oba, Sanchitagi and Garam Buhari are designated as D, E and F, respectively (Table 1) (Figure 1A and B). These are strategic locations in Ghana and Nigeria that were mainly chosen due to climatic and geographic regions that include southern and southern regions of both countries and areas with extensive agricultural activities. The pattern of rainfall seems favourable for agricultural productivity in the south of Ghana and Nigeria while the climate in the north is hotter and often experiences sporadic rainfall in both countries. At all six locations, peasant-farming practices are very common with traditional methods being used to provide food for immediate family.

Focus group and individual interview

A total sample of 54 small-scale farmers, including the village headmen (the person who is appointed as a leader of a village) and agriculture extension officers were present in 6 focus group meetings (FGMs) and 23 in-depth interviews at the six locations as described in Table 2. Six to twelve respondents were interviewed during the FGMs. The in-depth interviews took place after the FGMs, where 3 to 5 farmers were randomly selected to participate in a face-to-face interview. The 6 FGMs and 23 in-depth interviews were carried out using semi-structured questions relating to potential adoption of GM technology for improving crop productivity. The interview schedule comprised of different questions on broad areas of GM technology: Understanding, sources of information, application, training, concerns and benefits. During the FGMs/individual interviews, certain questions were asked, for example ''Have you used or heard about improved crop varieties before'' or ''Have you heard about GM crops before? Based on response to these questions, the number of participants were counted with regards to their knowledge on either improved crop varieties or GM crops.

After the first set of interviews, questions were modified based on matters arising. Given little or no understanding of GM technology among farmers, a brief unbiased, explanatory overview of GM technology was provided during the FGMs to stimulate discussion as described in the appendix. A similar approach was employed for studies carried out among small-scale farmers on potential adoption of GM technology in developing countries where a script was used during the discussions (Chong, 2005; Gonzalez et al., 2009;

Table 1. The locations and numbers of participants at the interviews in Ghana and Nigeria.

Country	Location	District	FGMs	Individual participant	Closest city (distance/km)
Ghana					
	A	Fianso	9	4	Brong Ahafo/Techiman (40 km)
	B	Cheyohi	10	5	Northern/ Tamale (10 km)
	C	Hodzo	7	3	Volta/Ho (5 km)
Nigeria					
	D	Oko Oba	12	5	South West/Lagos (15 km)
	E	Sanchitagi	10	3	South West/Ilorin (200 km)
	F	Garam Buhari	6	3	North Central/Abuja (100 km)

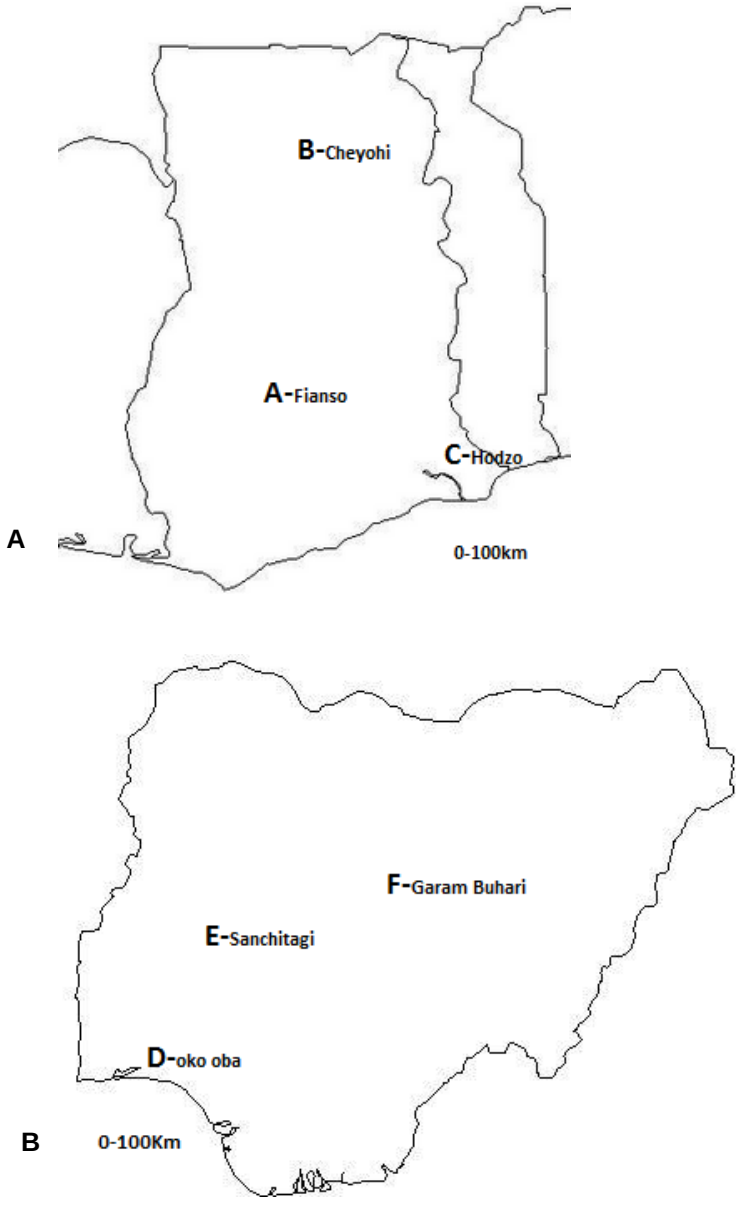

Figure 1. A, Focus group meeting sites (A, B, C) in Ghana; **B,** Figure 1 B: Focus group meeting sites (D, E and F) in Nigeria.

Table 2. Numbers of participants indicating genetically modified (GM) crop technology and traditional plant breeding (TPB) biotechnology awareness.

Country	Location	Focus group (GM/TPB biotechnology)	Individual participant (GM/TPB biotechnology)
Ghana			
	A	(0/9) 9	(0/4) 4
	B	(2/8)10	(2/3) 5
	C	(0/7) 7	(0/3) 3
Nigeria			
	D	(4/8)12	(4/1) 5
	E	(0/10)10	(0/3) 3
	F	(0/6) 6	(0/3) 3

Krishna and Qaim, 2007).

The focus group process was selected as the preferred research method because the study sought to find out whether the farmers would be willing to accept GM crops. This method is regarded as a non-directive means through which information is provided by the participants or respondents due to stimulation during the discussion, without being directed to answer specific questions (Krueger, 1994). A qualitative approach was chosen for this study because it offers the opportunity to explore a wider range of issues in much greater detail and also allows unexpected issues to arise that were not anticipated at the outset of the research (Britten, 1995). One disadvantage of focus groups is the reluctance to disagree if participants know each other and think it may cause friction later. As a result, relevant opinions may be missed during the interview. We mitigated this drawback by selecting individual participants after the focus group in each location to explore their views further on this topic as described in Table 2. At the end of the interview, a short questionnaire containing demographic information was completed by the farmers.

The interviews were tape recorded and notes taken simultaneously. The interview questions were asked in local languages and English. The interpretations in participants' spoken languages were appropriately carried out by a resource person who speaks the local language. In some cases, interpretation was not required, for example in location D, English was used throughout the interviews. Questions including the terminology used during the discuss ions were repeated in a few cases for clarity and better understanding so as to facilitate the interpretations in a consistent and identifiable way. Following all the interviews, audio recordings and notes were immediately transcribed for the analysis of results using a thematic analysis approach (Boyatzis, 1998), considering each quote, relevant point and phrase used.

The Ministry of Agriculture of each country government was officially contacted to secure permission to interview the farmers prior to the visits. Farmers were duly notified through the agriculture extension officers and village headmen of the locations about the interview on GM technology, stating the reasons for carrying out the interviews. All the necessary protocols were followed in regards of ethics, including allowing free choice regarding participation in the interviews.

Limitations

This study is subject to some limitations. Firstly, the study is discursive in nature, although it was not intended to describe the details of farm characteristics and their households through a comprehensive statistical analysis. Secondly, participants were counted with regards to using either improved crop varieties or having understanding of GM crops, and the number of participants counted were used in the Tables. Thirdly, small farmers were selected for the interviews; conclusions are limited to the number of farmers present at the interview. The background information on GM technology may have introduced a potential bias, but the likelihoods of such bias were reduced through the discussion with the agricultural scientists and biotechnologists before the interviews and not allowing the respondents to fully digest the information during the interviews. Although the discussion with the scientists/biotechnologists may have increased positive views on GM technology, the absence of anti-GM activists in FGM who would have disagreed otherwise is probably one of the limitations. Moreover, little or no mention of resource availability in background information that may be required in introduction of GM crops represents a major drawback in communication of the new technology to the respondents. Finally, our conclusion was interpreted within the context of the limitations.

RESULTS

Socio-economic characteristics of the farmers

The socio-economic characteristics of the farmers show that in Ghana, male and female represent 60 and 40%, respectively, (Table 3). While in Nigeria, male and female represent 69 and 31%, respectively. In both countries, the farmers in the sample were young, the average age of the farmer was 38 years with more than 10 years of farming experience. Table 3 indicates that 90% of the farmers were younger than 50 years. The average farm size is estimated at 2 ha. The majority of the farmers cultivate cassava representing 40 and 45% in Ghana and Nigeria, respectively. In Ghana, no education and school certificate account for 68 and 32%, respectively. While in Nigeria, no education, school certificate and higher degree account for 35, 48 and 17%, respectively.

Assessing the awareness, understanding and responses to potential acceptance of GM technology for improved health and crop productivity

The level of awareness and understanding of GM technology was extremely low in almost all the locations

Table 3. Socio-economic characteristics of respondents.

Socio-economic characteristics (N=54)	Ghana (average)	Percentage (%)	Nigeria (average	Percentage (%)
Gender				
Male	5.0	60	6.7	69
Female	3.3	40	3.0	31
Age				
21-40	4.3	52	5.7	59
41-50	3.3	40	3.7	38
>50	0.7	8.0	0.3	3.0
Religion				
Christian	3.3	40	6.3	66
Muslim	5.0	60	3.3	34
Marital status				
Married	7.7	92	8.0	83
Single	0.7	8.0	1.7	17
Types of crops				
Cassava	3.3	40	4.3	45
Potato	1.7	20	1.7	17
Yam	1.3	16	2.0	21
Maize	1.3	16	1.0	10
Others	0.7	8	0.7	7.0
Years of farming				
5-10	2.3	28	3.7	38
10+	6.0	72	6.0	62
Farm size/hectare(ha)				
<1	3.7	44	4.0	41
1-3	4.7	56	5.7	59
Education				
Higher degree (e.g. BSc)	0	0	1.7	17
School certificate (primary and secondary)	2.7	32	4.7	48
No education	5.7	68	3.3	35

visited among respondents. Most respondents know little or nothing about GM technology (Table 3). The village head men and extension officers also showed poor understanding of GM crops. When asked about their understandings on GM crops, most respondents mentioned improved crop varieties produced through traditional plant breeding biotechnology were GM crops. In an attempt to define GM technology, some respondents gave these answers below: Location A: ‘‘the GM technology produces healthy crops by crossing different varieties together’’; Location B: ‘‘Breeding a particular crop with another to produce desired traits’’; Location F: ‘‘Pure breeding of two crops to produce high yielding crop varieties’’; Location E: ‘‘Production of hybrid crops to fight diseases and pests’’. Only 6 out of 54 respondents (11%), (2 respondents, location B and 4 respondents, location D) claimed to have heard about GM technology before. The main source of awareness for this group of respondents was radio and newspapers.

When asked to define GM technology, two respondents answered as given below: Location B: ‘‘altering DNA of a particular crop and introduce into another one’’; Location D: ‘‘Production of genetically engineered crops to increase their productivities, values or ability to resist pests’’. The different definition given by the respondents in each location can be partly explained by their level of education and their familiarity with the traditional plant breeding and GM technology through media.

Overall, respondents showed a positive attitude towards potential acceptance of GM technology for improved health and crop productivity. The first two statements made by the respondents after gaining some understanding of GM technology as opposed to describing it as traditional plant breeding biotechnology are given as follows: Location C: ‘‘GM technology may provide nutritious and abundant food for our family and the communities as we cannot get this value from the other one’’; Location E: ‘‘if we can have GM crops that

Figure 2. Farmers holding infected sweet potato tubers in Ghana (Location A**).** A, Infected potato tubers; B, view of disease inside infected potato tubers. Source: Authors' field work.

are sweet and we can grow within a short period of time, we will be happy to apply GM technology''.

One of the first responses was improving or growing nutritious crops when considering the acceptance of GM technology. All respondents agreed that there was urgent need to grow GM crop traits with high nutritional value, particularly crops that contain more appropriate sources of proteins. The reason given for wanting to grow GM crops of nutritional benefits was that they could not afford to buy meat to increase their protein intakes. They complained that there was too much of intake of starchy foods and children suffered from malnutrition due to lack of protein and vitamin in their daily intakes. One respondent from location F said that ''maybe GM crops can give my children balanced diet''. Cassava, sweet potato and yam were mentioned as the types of food crops that needed nutritional improvement through GM technology. Respondents said that these crops were part of their daily food consumption and their nutritional value should be improved. In location E, one respondent in his early 50s stated that, ''yam is very important to me, my two wives and six children because we eat boiled and pounded yam every day... we need this kind of technology to provide nutritious yam''.

Some respondents wanted to know whether GM technology could be used to control pests and diseases. Respondents complained that crop production has suffered low yields due to the problem of pests and diseases. One respondent showed us a particular type of disease infecting sweet potato cultivated on almost 2.0 ha of farm land in location A (Figure 2). According to the respondent, this disease accounts for 30 to 50% yield loss in the past few years. As a result, this farmer experiences unstable sweet potato production and thus leads to low income and food shortages. Further, he stated that he would be a happy farmer if GM technology could truly solve this problem.

Moreover, it was a similar experience in almost all the locations surveyed where the majority of the farmers have used improved crop varieties, particularly cassava and maize. They felt the need for better agronomic performance of improved crop varieties through GM technology due to the problem of diseases and post-harvest deterioration. However, respondents acknowledged that improved crop varieties had performed better when compared to local crop varieties but they had to apply chemicals so as to have good results. For example, in location C, maize cultivation usually gives an average yield of 0.4-0.6 tons/ha, but with improved maize varieties and agro chemical treatment, an average yield of 1.2-1.8 tons/ha can be achieved.

Factors associated with the potential adoption of GM technology in farming practices

The village headman and extension officer of each location, and a few educated respondents in both countries gave strong opinions on the future adoption of GM technology. Some of the factors which may facilitate the adoption of this new technology were highlighted among this group of respondents and are described below. They felt these must be considered before GM could be successfully adopted by the small-scale farmers. Also some respondents shared views based on their farm experience particularly with regard to the adoption of improved crop varieties. They felt it could be applicable to the adoption of GM crops. Five factors were identified in the course of FGMs which are described below:

Cost of GM technology

Respondents expressed mixed feelings about the high cost that may be associated with the adoption of GM technology. One respondent (location D) said ‘‘the cost of GM technology fee may be too expensive for an ordinary poor farmer like me to afford’’. The respondent said further that ‘‘I have read in the paper that you cannot always get this technology free, there must be something to pay for it’’. A similar opinion was shared by another respondent (location B, village headman), ‘‘I heard from the news that it is an expensive technology because it has big benefit’’. Most respondents thought governments could provide it cheaper for small-scale farmers since they might not be able to afford it. As stated by one respondent (location A) that, ‘‘governments can provide subsidy for this kind of technology’’

Yield effect of GM crops

The yield effect of GM crop is one of the determining factors for the preparedness of whether to accept GM crops or not among small-scale farmers. Most respondents agreed that if production of GM crops could result in high yields, farmers would like to grow GM crops. The potential benefits of GM technology particularly in terms of increased yields was emphasised in location D and E, one respondent (location D) said, ‘‘as long as GM crops can benefit in terms of yields we are all going for it’’. This is corroborated by an undergraduate university student who has been farming with his father for more than 10 years (location E). As stated by this student ‘‘if we can benefit from GM crops, especially for high yields, I will encourage everybody in our village to accept it’’. In each location, respondents felt that yield was one of the first priorities to consider when growing any type of crops as it will generate more income, and it will be easier to assess or judge in the first two seasons of growing any adopted improved crop varieties or GM crops. Moreover, farmers were more likely to discourage each other if they experienced low yields during these periods.

Nutritional quality of GM food products

The taste of the food which may be associated with the nutritional quality of a potential GM food products stimulated interesting discussions among some respondents. They believed that taste was very important to get good market value. If GM crops can give better taste, many farmers would be ready to adopt and grow them. They said that most times the tastes were tested by the farmers before the crops were released into the local markets. For example, improved okra seeds were first planted by one farmer (location E), and the taste was better compared to local okra, according to the respondent. Due to the fact that the improved okra crops had better taste, it was distributed to the rest of the farmers. In location E, all respondents agreed that GM crops should go through a similar process before being released for local consumption.

Marketability of GM crops

There are other factors such as size, shelf life and suitability for cooking and processing that may determine the market value and pricing. Respondents mentioned that different types of crops have different specific markets. If GM crops were going to be adopted, those factors would also have to be taken into consideration as they could play an important role in determining their marketability. In location A, an illustration of previous experience on conventional crops versus improved crop varieties was cited. All respondents in this location explored the opportunity of FGMs to share their experience on consumer preference for conventional over improved crop varieties. These respondents said that some consumers preferred conventional or local cassava varieties to improved variety types as they were easy to cook with better taste. When compared with improved cassava varieties which were much bigger and suitable for food processing , for example, cassava processed into a local meal called ‘‘Fufu’’ (similar to mashed potato and often consumed on a daily basis) or processed into cassava chips for flour making and others used for domestic purposes.

However, some respondents argued that there were two types of improved cassava varieties: 1) One that was suitable for cooking like conventional cassava and, 2) another that was suitable for processing only. One respondent (location A) said that, ‘‘a particular type of improved cassava variety deteriorates faster than the other and not as good as conventional and another type of improved cassava variety combined’’. While opinions were diverse on conventional versus improved cassava varieties, a different opinion was expressed in terms of taste preference for improved cassava varieties and conventional in locations D and E, respectively. For example, one respondent (location E, extension officer) argued that some cassava varieties were not meant for consumption but due to the lack of information, some consumers have attempted to cook this particular cassava variety in the past. When asked for how they got this vital information on whether crops are suitable for cooking or not, respondents said that consumers give feedback on types of crops that are purchased from their farms. And that this kind of information helps in improving the quality of their farm produce so as to attract more consumers as well as retaining the market viability for their farm produce.

Growth period of GM crops

All respondents indicated interests in growing crops that require a short period of cultivation. During the FGMs, respondents mentioned that they would prefer short-growth cycle of improved crop varieties, particularly when they experienced low rainfall as it could save them money and time for irrigation. For example, planting maize that usually takes 4-5 months before harvesting, and growing GM maize whose period is shorter than 4 months will be good (location D). If there could be crops with such traits, they would be more willing to accept this new technology. While all respondents indicated an interest in shorter-growing cycle of crop varieties, not all of them felt the need to adopt GM crops based on its potential to grow within a short period of time only. However, most respondents emphasised potential GM crops with high yielding varieties plus ability to grow within a short given period of time.

Respondents' perception of potential risks of GM technology

Respondents were asked ''Do you think the introduction of GM crops into your traditional farming and consuming GM foods would be good or bad''. Most respondents were unconcerned about the potential health and environmental risks of GM crops. Respondents were happy eating GM food if it does not cause any health problem. One respondent (location F) said that ''as long as GM crop does not pose threat to our health we will grow and eat it''. However, a few educated respondents in location D felt the need to control the introduction of GM crops into their farming system in the future as they have heard about the potential negative impact on ecosystem. In the same location, one female respondent raised concern about the potential health risk of GM crops based on previous news of contaminated food and wrong application of fertilizer in the northern part of Nigeria. According to her, ''I heard that farmers died as a result of wrong application of fertilizers and consumption of food contaminated fertilizer and... we do not know anything about GM food because people may hesitate to buy food that are not natural''. The majority of respondents would rely on scientific evidence and information from local scientists before they cultivate GM crops. Respondents emphasised that scientists must come out with the facts that are convincing enough to believe that GM crops are suitable for the environment and safe for human consumption before GM crops can be accepted.

Based on the comments above, respondents were asked about how they would get support or training to grow GM crops. Most respondents felt that government should be able to support them in term of trainings if they showed interest in introducing GM technology. One of the respondents (location C) indicated that special training is required particularly for the safety aspect of handling GM products. The respondent said further, ''because GM crop is different from improved crop varieties, I think we need special training''. This is supported by similar views (location D and B) that trials should be undertaken in various farm plots under different prevailing conditions such as fertile and poor soil, raining and dry seasons, and growth period of GM crop traits, while local varieties are used as control plots. Some respondents argued that whether the trainings required to grow these types of crops will be provided at the right time can be one of the determining factors in adopting GM technology.

DISCUSSION

This study assessed the perception of farmers about the potential acceptance of GM technology in Ghana and Nigeria. The majority of the respondents expressed similar views across the locations, particularly in terms of potential benefits of GM technology for improving health, food security and crop productivity. While the majority of the farmers may be excited about the potential of GM technology, it does not mean the new technology will be available anytime soon or will start making impact when successfully developed, for a variety of reasons as discussed in this section.

The potential use of GM technology for improving root and tube crops such as cassava, sweet potato and yam received a lot of attention during the interviews. Cassava received most attention among other root and tuber crops because it is eaten as a staple food and widely cultivated as a viable cash crop by more than 80% of poor subsistence farmers in this region (Table 3). This indicates that cassava will continue to play an important role as food security crop in both countries. Whilst GM technology has been touted to solve to part of food security problems in Africa, there is no evidence yet to show direct link between adoption of GM crops and food security (Adenle, 2013). The nutritional quality of GM products that is associated with taste can also be important in the acceptance of new technology in the two countries. Most respondents felt that GM cassava with better taste can encourage the adoption of GM crops as consumers would prefer cassava products that are palatable and easy to cook. Factors such as high-yielding, disease resistant and shorter growth-cycle varieties are important traits that will encourage farmers to adopt GM products in view of low crop productivity and other agronomic problems in this region. The important question raised by Adenle et al. (2012) is: Can these traits be successfully incorporated into farmer preferred cultivars in view of disconnect between farmers and local

scientists in Africa? Of course, failure to incorporate farmers local preferred cultivars may limit the adoption of GM technology in Ghana and Nigeria.

The lack of mention of important factors in facilitating the adoption of GM crops in the literature, particularly in African countries, remains a concern. Some scholars often assume that farmers in Africa will choose GM varieties over other crop varieties due to low yield and pest and disease problems (Mugo et al., 2005; Sayre et al., 2011; Smale and De Groote, 2003) with little mention or detail of the factors that can facilitate the adoption. For example, ‘‘Resistant maize (GM) varieties are likely to be widely adopted and provide major returns to the research investment’’ (Mugo et al., 2005). This can be misleading without taking other factors into full consideration. The fact that farmers in this study are willing to accept GM crops does not mean all will go down well if Ghanaian or Nigerian government fails to support the farmers on how to adopt the new technology. Several empirical evidence from an early literature on adoption of new technology, has demonstrated that poor farmers in developing countries are risk averse and hesitant in decision making, and that the adoption of new technology is influenced by different factors, for example, the cost of the new technology (Antle, 1987; Binswanger, 1980; Dillon and Scandizzo, 1978).

The cost of GM technology will be one of determining factors in adopting GM crops in Africa in the future. In view of high cost of regulation for new GM products (Potrykus, 2010), developing GM staples crops might not be a priority for many African country governments. For example, a study suggests that high cost of regulation causes delay in developing and regulating GM vegetables mainly grown by traditional farmers in South Africa (Adenle et al., 2013). Contrary to the assumptions of scholars mentioned above, small and risk-averse farmers may be hesitant to adopt a new GM crop variety due to the cost of improved seeds, potential health and environment risks associated with the new technology (Scandizzo and Savastano, 2010; Soleri et al., 2008). A study by Soleri et al. (2008) tested the assumptions regarding preference of transgenic (GM) maize varieties over traditional and other varieties among farmers in developing countries such as Cuba, Guatemala and Mexico. The authors showed that only 13.7% of the farmers would choose GM maize over non-GM varieties despite high-yielding traits of the former partly due to the need to purchase GM seed every season, and that GM varieties yields can decline over time due to the evolution of pest resistance. This study indicates that only small proportion (9.6%) of farmers had heard of GM technology before which is almost similar to (11%) of farmers in our study. However, the majority of respondents preferred to avoid GM varieties in the same study, which contrasts our study. The difference between the two studies can be partly explained by the fact that many farmers in the study of Soleri et al. (2008) have had long-term experience using improved varieties (for example, hybrid maize) which alerted them to potential risks from new technology as described by the authors. While farmers in our study had occasionally used improved varieties suggesting that their little experience may have affected rational evaluations of variables for adopting a new technology. Another difference is that the methodology described by (Soleri et al., 2008) presented a narrative scenario between the adoption of GM and non-GM varieties whilst eliciting farmers’ opinions which was not used in our study. Although, another finding that used similar methodology showed that farmers’ perception toward GM technology is driven by economic benefits (Chong, 2005), which is consistent with our study.

Moreover, cost of regulation can represent a significant challenge to development and adoption of GM crops. A study by Bayer et al. (2010) argue that high cost of compliance with biosafety regulation may deter a small firm or public institutions to develop and commercialize GM products, particularly in developing countries. The authors estimated the cost of compliance with biosafety regulation before GM maize can be released in GM producing countries such as India and Philippine at US$ 1.5 million and 1.7 million, respectively (Bayer et al., 2010). This experience may not be different from Ghana and Nigeria before GM crops are released to the farmers. Although, Bayer et al. (2010), caution that regulatory cost may decline as countries gain experience with the use of GM products because changes to regulatory framework can reduce other associated costs.

The introduction of GM crops in Ghana and Nigeria will require special care and training that is completely different from traditional practices in the two countries which may incur additional cost. A previous study analyzed farmers’ attitudes in Sweden towards GM crops and showed that they were concerned about their ability to sell in the market due to additional technology fees associated with buying GM maize seed (Lehman and Johnson, 2008). Another study (Scandizzo and Savastano, 2010) argue that adoption of GM crops may require some investment in land preparation, terracing, irrigation and acquisition of machinery. This may be largely applicable to large scale farmers with the economy of scale as development of GM crops based on preferred local cultivars might not necessarily require a huge investment, hence targeting local cultivar traits in the development of new GM products in the two countries can facilitate the adoption by the small-scale farmers. The current cultivation of GM maize in South Africa requires refuge implementation to control the stem borer infestation in order to have increase in yields and some farmers do fail to implement the refuge (Kruger et al., 2011). According to Kruger et al. (2011), the reasons given for not implementing mandatory refuge among these farmers in South Africa was due to time-consuming

and labor intensive nature of refuge program, leading to extra cost in adopting the new technology. The extra cost required in implementing refuge can also influence decision of farmers in Ghana and Nigeria as to whether or not to adopt the new technology. As suggested by Scandizzo and Savastano (2010), all of these can be described as sunk costs which are associated with the learning, technical training and experimentation of new technology. In spite of the costs associated with either obtaining GM seeds or insect resistance management, proponents of GM crops have shown that small-scale farmers benefited from adoption of GM crops. A study by Gouse (2012) and Gouse et al. (2005) showed that small-scale farmers who paid more for GM maize seed enjoyed increased yield and better income over conventional maize seed varieties through labor saving and pesticide reduction in South Africa. This suggests that higher prices of GM seeds may not necessarily discourage small-scale farmers from adoption of GM crops, as potential economic benefits of GM crops could be a key factor in adopting the new technology.

Low level of education among farmers could undermine the adoption of new technology in the light of technical training required to grow GM crops in the two countries. For example, almost 70% of farmers interviewed in Ghana have no basic education such as primary or secondary school leaving certificate (Table 3). The lack of basic education among farmers could be a serious challenge in introducing this new technology. One of the key observations in this study was that respondents with relative high level of education particularly in local D, for example, a graduate degree equivalent, valued potentials risks and benefits of GM crops than those without education or whose level of education was lower in majority of the locations. The provision of inefficient services by extension workers could limit the adoption of GM crops in the two countries. Past experience suggests that any farm product resulting from technology other than the traditional one can receive resistance in the market. For example, lack of right information was due to wrong domestic utilization of improved cassava varieties as explained by the respondents, hence resulting in limited acceptance.

The controversy surrounding the use of GM technology, particularly with regard to environment and health risk, still poses a big challenge to adoption of the new technology around the world including Africa. The lack of scientific capacity to regulate and release GM crops to farmers represent a significant challenge in Ghana, Nigeria and other African countries (Adenle et al., 2013). One wonders which regulatory authority either in Ghana or Nigeria has scientific capacity to test and conduct risk analysis of GM products, and demonstrate it as safe for human consumption and less harmful to the environment. While Ghanaian biosafety bill has been approved by the President, Nigerian president is yet to approve its biosafety bill, thereby hindering the use of GM products in the country (Adenle, 2013). As long as there is no consensus or acceptable standard as to how to regulate and use GM products, adoption of GM crops by the farmers and market acceptance by the consumers may be difficult, even when locally preferred cultivars are successfully developed in Ghana and Nigeria.

Furthermore, factors such as cultural and spiritual basis could play an important role in their decision to accept GM which needs careful consideration in policy development (Amin et al., 2011; Soleri et al., 2008). While we did not specifically ask respondents whether religions would influence their decisions in accepting GM crops or not, Nigerian christians and Ghanaian muslims that were interviewed represent 66 and 60% respectively, suggesting that religion might not necessarily affect farmers decision in accepting GM crops in these locations as most respondents in both countries appreciate potential benefits of GM crops.

This study has formed a basis through which further research work can be undertaken on GM technology in this region. Some of the challenges described in this study should not be viewed as an attempt to undermine the introduction of GM technology in this part of Africa, but rather to identify fundamental issues that could impede any new technology and find potential solutions. Before GM technology can make any impact in terms of food security or provide improved health, there is need to investigate, plan, evaluate and implement variables which determine success of a new technology but often missed out in the debates. Moreover, better training of farmers, raising the awareness and educating the public, increasing scientific capacity, engaging local scientists and farmers, upgrading infrastructure and capacity building among others represent an important step in development and adoption of new technology.

The role of the private technology developer/seed companies is very important as we know that extension services, especially for new technologies are not available in many parts of Africa including Ghana and Nigeria. South Africa is a good example, where technology developers are trained and after-sale services are provided to the farmers. Similarly, the private Indian seed companies have on-farm demonstration to facilitate technology transfer (Personal Communication). African governments must put in place a strong mechanism for protecting intellectual property rights (IPRs) as this can encourage multinational corporation to invest in new GM crops. This was emphasised at the recent workshop with the Monsanto, led by Director General of the National Biotechnology Development Agency, Nigeria, particularly to establish domestic institutions that will build core competencies in IPR system.

Finally, the proponent of GM technology and policymakers should not always think introducing the new technology to Ghana or Nigeria and the rest of the Africa

will start making immediate impact without emphasizing underlying constraints and what need to be done to overcome these constraints before farmers can adopt and enjoy the benefits of the new technology.

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REFERENCES

Adenle AA (2013). Stakeholders' perceptions of GM technology in West Africa: Assessing the responses of policymakers and scientists in Ghana and Nigeria. J. Agric. Environ. Ethics In press

Adenle AA, Aworh GC, Akromah R, Parayil G (2012). Developing GM super cassava for improved health and food security: future challenges in Africa. Agriculture and Food Security, 1:11.

Adenle AA, Morris EJ, Govindan P (2013). Status of development, regulation and adoption of GM agriculture in Africa: Views and positions of stakeholder groups. Food Policy 42:159-166.

Amin A, Azlan NAA, Hashim H, Ahmad J (2011), Ethical Perception of Modern Biotechnology. Afr. J. Biotechnol. 10(58):12435-12447.

Antle JM (1987). Econometric estimation of producers' risk attributes. Am. J. Agric. Econ. 69(3):509-522.

Bayer JC, Norton GW, Falck-Zepeda J (2010). Cost of compliance with biotechnology regulation in the Philippines: Implications for developing countries. AgBioForum 13(1):53-62.

Binswanger HP (1980). Attitudes towards risk: Experimental measurement in rural India. Am. J. Agric. Econ. 62:395-407.

Boyatzis R (1998). Transforming Qualitative Informations: Thematic Analysis and Code Development. Sage, Thousand Oaks.

Britten N (1995). Qualitative Research: Qualitative interviews in medical research. BMJ 311:251.

Chong M (2005). Perception of the risks and benefits of Bt egg-plant by Indian farmers. J. Risk Res. 8(7-8):617-634.

Dillon JL, Scandizzo PL (1978), Risk preferences of subsistence farmers in northeast Brazil. Am. J. Agric. Econ. 60(3):425-435.

FAO (2009). Food and Agricultural Organization of the United Nations (FAO), State of Food Insecurity in World 2009. (FAO, Rome, 2009).

FAO (2010). Food and Agricultural Organization of the United Nations (FAO): World Hunger and Poverty Facts and Statistics. World Hunger Education Service

Finger R, Hartmann M, Micheal F (2009). Adoption pattern of herbicide-tolerant soybeans in Argentina. AgBioForum 12:404-411

Gonzalez C, Johnson N, Qaim M (2009). Consumer Acceptance of Second-Generation GM Foods: The Case of Biofortified Cassava in the North-east of Brazil. J. Agric. Econ. 60:604-624.

Gouse M (2012). GM maize as subsistence crop: The South African smallholder experience. AgBioForum 15(2):163-174.

Gouse M, Pray C, Kirsten J, Schimmelpfening D (2005). A GM subsistence crop in Africa: the case of Bt white maize in South Africa'. Int. J. Biotechnol. 7:84-94

James C (2013). Global Status of Commercialized Biotech/GM Crops: 2012 (ISAAA Brief No. 44) International Service for the Acquisition of Agri-biotech Applications, Ithaca, NY.

Kaup BZ (2008). The Reflexive Producer: The Influence of Farmer Knowledge Upon the Use of Bt Corn. Rural Sociol. 73(1):62-81.

Kolady D, Lesser W (2005), Adoption of Genetically Modified Eggplant in India:-An *Ex Ante* Analysis.Selected Paper Prepared for Presentation at the American Agricultural Economic Association Annual Meeting, Providence, Rhode Island, July 24-27.

Krishna VV, Qaim M (2007), Estimating the adoption of Bt eggplant in India:Who Benefits from public-private partnership? Food Policy 32: 523-543

Krueger RA (1994). Focus groups: A practical guide for applied research. Second Edition. London: Sage Publication.

Kruger M, Van Rensburg JBJ, Van den Berg J (2011). Transgenic Bt maize: farmers' perceptions, refuge compliance and reports of stem borer resistance in South Africa. J. Appl. Entomol. 136:38-50.

Lehman A, Johnson K (2008), Swedish farmers attitudes, expectations and fears in relation to growing genetically modified crops. Environ. Biosafety Res. 7:153-162.

Mugo S, De Groote H, Bergvinson D, Mulaa M, Songa J, Gichuki S (2005). Developing Bt maize for resource-poor farmers -Recent advances in the IRMA project. Afr. J. Biotechnol. 4 (13):1490-1504.

Nordling L (2012). Africa Analysis: Kenya sending the wrong message about GM foods. Scidev.net, December 7.

Pinstrup-Andersen P (2009). Food security: definition and measurement. Food Sec. 1:5-7

Potrykus I (2010). Lessons from the 'Humanitarian Golden Rice' project: regulation prevents development of public good genetically engineered crop products. New Biotechnol. 27:466-472

Sayre R, Beeching JR, Cahoon EB, Egesi C, Fauquet CM, Fellman J, Fregene M, Gruissem W, Mallowa S, Manary M, Maziya-Dixon B, Mbanaso A, Schachtman DP, Siritunga D, Taylor N, Vanderschuren H, Zhang P (2011). The BioCassava Plus Program: Biofortification of Cassava for Sub-Saharan Africa. Annu. Rev. Plant Biol. 62:251-272.

Scandizzo PL, Savastano S (2010). The adoption and diffusion of GM crops in United States: A real option approach. AgBioForum 13(2):142-157.

Smale M, De Groote H (2003), Diagnostic research to enable adoption of transgenic crop varieties by smallholder farmers in Sub-Saharan Africa. Afr. J. Biotechnol. 2:586-595

Soleri D, Cleveland DA, Glasgow G, Sweeney SH, Cuevas FA, Fuentes MR, Rios L H (2008), Testing assumptions underlying economic research on transgenic food crops for Third World farmers: Evidence from Cuba, Guatemala and Mexico. Ecol. Econ. 67:667-682

APPENDIX

Background information on GM technology

We described GM technology as a way of introducing a gene from organism to another crop of interest for a variety of purposes by the scientists. For example, a gene can be taken from organism and inserted into crop to increase the yield or create crop (e.g. cassava) with vitamin or protein. And if these crops are available, it means that farmers can have better income, use less harmful chemicals (for example, pesticides) and high-protein foods can become available to the farmers to improve their health. Some people think that GM crops can benefit farmers and consumers due to these advantages, while some think GM crops are not natural due to possible long-term environmental and health human effects. We think it is important to share this vital information about GM crops. We would like you to tell us from your mind about what you may benefit from adopting GM crops and any problem that may result from using GM crops.