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Prospects and constraints faced by smallholder farmers in the cultivation of GM crops: A case study from Northern Ghana

Zakaria H.[1*], Obeng F. K.[1], Quainoo A. K.[2] and Abujaja A. M.[3]

[1]Department of Agricultural Innovation Communication, Faculty of Agriculture, Food and Consumer Sciences, University for Development Studies, Box 1882 Tamale, Ghana.
[2]Department of Biotechnology, Faculty of Agriculture, Food and Consumer Sciences, University for Development Studies, Box 1882 Tamale, Ghana.
[3]Department of Agriculture and Consumer Science Education, University for Development Studies, Tamale, Ghana

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As Ghana prepares to commence commercialization of Genetically Modified (GM) crops, this paper reports findings of a survey that sought the views of smallholder farmers in northern Ghana on the likely prospects and constraints of GM crops cultivation. Multi-stage sampling techniques were employed to sample 360 smallholder farmers across ten districts in northern Ghana with interviews, guided by semi-structured questionnaires, and focus group discussions used to gather data for the study. Descriptive statistics and Kendall's coefficient of concordance were applied to analyze the data gathered. The prospects of GM technology according to the smallholder farmers surveyed were that GM technology can be used to breed drought-tolerant, early maturing, and high yielding local crop varieties and also help reduce the cost of weed, pest, and disease control. While their perceived constraints to the cultivation of GM crops were the probably high cost of GM seed, unreliable supply of GM seed, likely failure of regulatory agencies, and possible environmental and health risks among others. It is recommended to the Ministry of Food and Agriculture (MOFA) and other relevant organizations to address farmers' concerns and reservations over the possible high cost of GM seeds and the fear that GM seed supply might not be reliable.

Key words: Prospects, constraints, GM crops, agricultural biotechnology, smallholder farmers, northern region of Ghana, biosafety.

INTRODUCTION

Developing countries largely dependent on agriculture and agriculture based industries (Bargali et al., 2004, 2009a; Mishra et al., 2010; Vibhuti et al., 2020). Poverty, population pressure, agricultural expansion and intensification and development of infrastructure have been suggested as major threats to biodiversity in the tropics (Davidar et al., 2010; Kittur et al., 2014; Baboo et al., 2017; Karki et al., 2017; Mourya et al., 2019). All

*Corresponding author. E-mail: azkariahudu@gmail.com/hzakaria@uds.edu.gh.

these factors are cumulatively responsible for the soil degradation (Bargali et al., 2019; Karki et al., 2021a, b)which leads smallholder farmers (Vibhuti et al., 2018) particularly in developing countries to look over towards the high yielding verities and genetically modified (GM) crops (Arora et al., 2011).

In the history of crop improvement, the introduction of GM crops through genetic engineering had been the most controversial plant breeding technique in recent history of agricultural research and development. The underlying constructs surrounding narratives of the on-going debate on GM crops are largely issues relating to potential risks and uncertainties that the cultivation and consumption of GM crops might pose to human and animal health, and the possible negative consequences it might pose to the environment and biodiversity (Biden et al., 2018; Brookes and Barfoot, 2017b; Mampuys and Brom, 2015; Raman, 2017; Qaim, 2015). Other issues often raised in the debate include arguments regarding threats to national food sovereignty and political economy (Azadi and Ho, 2010; Fukuda-Parr and Orr, 2012; Katiraee, 2014; Leonelli, 2019; Naylor, 2017) and the possible distortion of international trade regulations due to lack of harmonization of domestic standards and regulations regarding exports and imports of agricultural commodities containing GMOs (Bhuiya, 2012; Fukuda-Parr and Orr, 2012; McDonald, 1985 Katiraee, 2014; Shiva, 2006).

These concerns about the development of GM crop varieties have raised a wide range of new legal, ethical and economic questions in agriculture. As a result, there is a growing body of literature highlighting the positive socio-economic and environmental impacts of GM while others raising issues with possible negative consequences on socio-economic impacts as well as health and environmental risks and uncertainties (Biden et al., 2018; Brookes and Barfoot, 2017a; Mampuys and Brom, 2015; Raman, 2017; Qaim, 2015).

Despite the raging debate global cultivation of GM crops have continued to spread throughout the world with global production increasing at a geometric rate. In 2014, a record of 181.5 million hectares of GM crops were grown globally (James, 2014) registering an increase of more than six million hectares from 175 million in 2013. The increasing adoption and cultivation of GM crops have brought impressive socio-economic and environmental benefits to the 28 countries in which over 17 million farmers are engaged in its cultivation. Thus within the second and half decades of its commercialization, global hectares of GM crops have increased more than 1000-folds soaring from 1.7 million hectares in 1996 to about 200 million hectares in 2018 (Brookes and Barfoot, 2019, 2018), making GM crops the fastest adopted crop technology in contemporary agricultural innovation adoption history. This high rate of adoption is a strong vote of confidence in GM crops, reflecting farmer satisfaction in both industrial and developing countries.

Evidence available demonstrates that developing countries have planted more GM crops than the industrial countries. Figures from International Service for the Acquisition of Agri-biotechnology Applications (ISAAA, 2016) indicate that in 2016, 19 developing countries planted 54% (99.6 million hectares) of the global GM hectares, while 7 industrial countries took the remaining 46% (85.5 million hectares) share. Due to increasing realization of the role of GM crops in agricultural development among policy makers in developing countries leading to increasing adoption of GM crops particularly Bt cotton in many developing countries, this trend is expected to continue in the upcoming years (Brookes and Barfoot, 2017a; ISAAA, 2016). Similarly James (2014) observed that smallholder farmers adoption of GM crops in developing countries continue to grow at impressive rate year after year with a potential of not only improving farm income but reducing food insecurity among rural communities.

Recent studies by Brookes and Barfoot (2017a) in their annual update analysis shows that there continues to be very significant net economic benefits at the farm level amounting to $15.4 billion in 2015 and $167.8 billion for the 20 year period 1996-2015 (in nominal terms). Over half (51%) of these gains have accrued to farmers in developing countries. About 72% of the gains have derived from yield and production gains with the remaining 28% coming from cost savings. The technology has also made important contributions to increasing global production levels having, for example, added 180 million tonnes and 358 million tonnes respectively, to the global production of soybeans and maize since the introduction of the technology in the mid-1990s.

The application of modern biotechnology as a tool for crop improvement is increasingly being regarded in Ghana as a promising technology not only for the attainment of food security in the country, but also for the overall living conditions of the population (Ashitey, 2013; MES/UNEP-GEF, 2004). Within two decades now, after the country ratified the Convention on Biological Diversity on August 29, 1994 and the Cartagena Protocol on Biosafety on May 30th, 2003 steady progress have been made by way of biotechnology policy directions, regulatory and institutional frameworks being put in place to ensure safety application of biotechnology in crop improvement and agricultural development in general (Agorsor et al., 2016; Ashitey, 2013; Sarpong, 2004). In guiding the country's agrobiotechnology process, national biosafety framework was drafted in 2004 with the support from the United Nations Environment Programme (UNEP) - Global Environment Facility (GEF) (MES/UNDP-GEF, 2004). The adoption of national biosafety framework assisted in giving policy directions for enactment of the country's biosafety legal and regulatory regimes in preparations towards the eventual uptake of GMOs technology in commercial agricultural production. As observed by Ashitey (2013) that the adoption of National Biosafety Framework in Ghana has paved way for the final passage of the country's biosafety law.

Also between 2004 and 2008, Ashitey (2013) noted that through USAID-sponsored Programme for Biosafety Systems (PBS), implemented by a consortium led by the International Food Policy Research Institute (IFPRI), significant efforts were made in developing the underlying legal framework for biotechnology and biosafety policy in Ghana. Also from 2009 to 2011 the country together with Burkina Faso, Kenya, Malawi, Nigeria and Uganda benefited from the Forum for Agricultural Research in Africa (FARA), project on Strengthening Capacity for Safe Biotechnology Management which had helped in addressing information gathering and dissemination, awareness creation, outreach, and stewardship in biotechnology (FARA, 2012).

All these efforts culminated in the enactment of Biosafety Act (Act 831) in 2011 which provides legally enacted law to guide the generation and application of GMOs. Unlike other countries, Ghana biosafety law was passed without much controversy and debate, even though there were issues raised against the law by campaigners against GMOs after the law was passed and acceded to by the president (Zakaria, 2014; Ashitey, 2013). Notwithstanding, Food Sovereignty Ghana (FSG), a civil society organization, sought court injunction against a plan release of Bt cowpea and GM rice by Council for Scientific and Industrial Research (CSIR) at the Human Rights Division of the Accra Fast Track Court which was thrown out giving further impetus to the Ghana agrobiotechnology agenda (GNA, 2015). The objective of the Act is to: (a) ensure adequate level of protection in the field of safe development transfer, handling and use of genetically modified organisms resulting from biotechnology that may have an adverse effect on health and the environment, and (b) establish a transparent and predictable process to review and make decisions on genetically modified organisms and related activities (Biosafety Act, 831, 2011).

However, currently the only regulatory framework guiding seed generation, production, certification and marketing in the country is the Plants and Fertilizer Act (Act 803, 2010). This law does not explicitly made provision for the protection of breeders intellectual property right (Ashitey, 2013) which is critical in getting private investment in varietal development, especially novel technology like GMOs, which require heavy investment. It is to overcome this shortcoming that Plant Breeders' Bill was drafted which is currently being considered by Ghanaian parliament to provide legal basis for protecting intellectual property of plant breeders and research institutions applying GMOs technology in producing improved varieties of crops.

This will create a favourable environment for the development and commercialization of biotechnology seeds and crops as observed by Ashitey (2013) and also attract private investment in GM seeds production and marketing. As observed by Bennett and Jennings (2013) that progress had been made in respect to enactment of enforceable regulatory framework for GMOs in Ghana, and as such the country can be considered to have positive stance towards commercialization of GM crops. Therefore the passage of the Plant Breeders' Bill into enforceable law is critical to Ghana biotechnology agenda. The Bill provides for clear procedure for the application and approval or otherwise of plant breeders right so as to safeguard private sector investment in biotechnology seed production.

With regard to progress in biotechnology research and GM crops development and commercialization, Savannah Agricultural Research Institution (SARI) of the Council for Scientific and Industrial Research (CSIR) is currently undertaking adoptive trials and research into genetically modified cowpea and cotton. SARI had established a biotechnology cowpea farm at Nyankpala in the Tolon District and a biotechnology cotton farm at Kpalkore in the Mion District (Agorsor et al., 2016; Ashitey, 2013; GNA, 2015).

Despite this steady progress Ghana had made toward commencement of commercialization of GM crops, very little is known from the perspective of smallholder farmers in the country on prospects and constraints GM crops cultivation will hold for them. Ademola et al. (2014) highlighted the important benefits of GM crops to smallholder farmers in Ghana and Nigeria. But their study did not examine the potential benefits of GM crops cultivation from the perspective of smallholder farmers themselves. Also Agorsor et al. (2016) examined genetic engineered crops in Ghana agriculture by assessing the state of Ghana's GM crop commercialization from research on confined field trial and GM crops undergoing assessment for commercial release. However, the question of potential benefits and constraints smallholder farmers might face in adopting the cultivation of GM crops from the perspective of Ghanaian smallholder farmers remained largely unanswered. The objectives of the present study are to examine the prospects and constraints of GM crops cultivation from the perspective of smallholder farmers in Northern Ghana.

METHODOLOGY

The study was conducted in Northern Ghana, comprising of the then three northernmost administrative regions, namely, Northern, Upper East and Upper West regions. However, in recent times two additional regions – namely North East and Savannah regions have been curved out of the then Northern. The northernmost regions of Ghana lies in the Guinea Savannah ecological zone characterised by grasslands intersperse with trees and shrubs. The climate and weather pattern are mainly erratic with low humidity level and unimodal rainfall pattern. The soils are fragile and less fertile compared with southern Ghana (MOFA, 2010). With agriculture being the main occupation of majority of the people of northern

Table 1. Distribution of sample size by region and districts.

Region	No of Districts in the Northern Ghana	No of sampled Districts	No of FBOs in the region	No of FBOs in sampled Districts	No of Sampled FBOs	Members of FBOs to be sampled
Northern	26	5	2,573	584	74	222
Upper East	13	3	943	220	28	84
Upper West	11	2	772	140	18	54
Total	**50**	**10**	**4, 288**	944	**120**	**360**

Source: Authors (2015).

Ghana coupled with poor soils and unimodal erratic rain fall pattern, the area is the poorest part of the country with high level of food insecurity, malnutrition and low standard of living as revealed by GSS (2017) in the Seventh Around of Ghana living Standard Survey (GLSS7).

To help improve agriculture in northern Ghana, Savannah Agricultural Research Institute (SARI), one of the thirteen research institutes of the Council for scientific and Industrial Research Institute (CSIR) was established and had been operating for several decades now. SARI in line with its mandate of conducting research to generate appropriate technologies to increase food and fibre crop production based on a sustainable production system which maintains and/or increases soil fertility' had contributed greatly to improving the lives of crops farmers in the area and Ghana at large (SARI, 2012).

The Northern region of Ghana was selected for this study because SARI is undertaking adaptive and contained trials on genetically modified cowpea and cotton (Bt cowpea and Bt cotton) (GNA, 2015; IFPRI, 2014). Pending commercial release, SARI had established a biotechnology cowpea farm at Nyankpala in the Tolon District and a biotechnology cotton farm at Kpalkore in the Mion District (Agorsor et al., 2016; Ashitey, 2013; GNA, 2013). These trials had reached their final stage for commercial release for some time now which will lead to seeds multiplication and eventual release to farmers for commercial production (Agorsor et al., 2016; Ashitey, 2013).

Research design

Descriptive cross-sectional survey design was adopted for this study in order to collect data and describe smallholder farmers' perceived prospects and constraints likely to be faced when GM seeds are released to them for commercial production. Descriptive cross-sectional survey design is a most basic type of enquiry that aims to observe (gather information on) certain phenomena, often at a single point in time using cross-sectional survey to examine a situation by describing important factors such as demographic and socio-economic, behaviours, attitudes, experiences, and knowledge (Kelley et a., 2003).

Sample size and sampling process

The study surveyed farmers who were members of Farmers Based Organizations (FBOs) in northern Ghana. FBOs are the grassroots farmer representation in Ghana. The Ministry of Food and Agricultural (MFOs) through their district offices facilitation the formation of these FBOs in order to ensure effective dissemination of agricultural information and as means of soliciting smallholder farmers inputs to policy and implementation of agricultural projects and programme. Cochran's (1977) sample size determination formula was employed in calculating the sample size used in this study. Applying Cochran (1977), sample size (n) computation formula as:

$$n = \frac{N}{1+Ne^2} \quad (1)$$

Where: n = Sample size; N = Population of crop based FBOs in the Northern Ghana; e = margin of error (0.1)

With the population of 4,288 crops based FBOs in the Northern Ghana sourced from the various regional agricultural directorates and FBOs website, the sample size was calculated as:

$$n = \frac{4,288}{1+4,288(0.1)^2} \quad (2)$$

n = **97.7** rounded up to 98 FBOs. Applying 20% correction factor increased the targeted sampled size to 118, which was then rounded up to 120 FBOs. From each of the 120 sampled FBOs, three members who have ever head and/or read about GM crops were selected bringing the total sample size to 360 members of FBOs. Famers belonging to FBOs were targeted because the FBOs are the grassroots farmer groupings who are often consulted in the design and implementation of agricultural policies by government.

Multi-stage sampling procedures were adopted in selecting respondents for the study. We started by stratifying the study area into three strata, where the three regions – northern, upper east and upper west constitutes the strata. Simple random sampling technique, using the lottery method, was employed to sampled districts within each region based on proportional representation. Only districts with registered FBOs whose contact details were on the portal of FBOs in Ghana captured on the website of MOFA for 2015 available on http://fboghana.com/ and those whose contact persons were obtained at the regional agricultural development units were considered for sampling. This was followed by purposive sampling of crop based FBOs and members of FBOs who have ever heard and/or read about GM crops from sampled districts. FBOs within the reach of the sampled districts were sampled using lottery method of simple random sampling technique and based on proportional representation.

Kasena/Nankana East District, Bolgatanga Municipality and Bawku West District were sampled from the 13 Districts in the Upper East Region while Nadowli/Kaleo District and Wa Municipality were sampled from the 11 Districts in the Upper West Region. And Bole District, West Mamprusi District, Savelugu/ Nanton Municipality, Gushiegu District and Nanumba North District were sampled from the 24 eligible Districts in the then Northern Region. From the list of sampled district three smallholder farmers who have ever heard and/or read about GM crops were purposively selected bringing the total smallholder farmers sampled to 360. Table 1 presents the distribution of sample district, FBOs and smallholder farmers.

Also five focus group discussions, three in northern region and one each in the upper east and west regions were held with an average of 9 participants for each focus group discussion. In all forty seven participants took part in the focus group discussions. In addition, in-depth interviews prior to the actual field survey were conducted with thirteen key informants comprising of ten leaders of FBOs and three commercial farmers across the three regions. Thus the total participants in this study were four hundred and twenty comprising of 360 smallholder farmers who were members of FBOs, forty seven participants of the five focus group discussions held and thirteen key informants.

Data collection process and analysis

Both qualitative and quantitative data were collected from primary and secondary sources. Field survey, comprising personal observations, focus group discussions, key informant interviews and personal interviews guided by semi-structured questionnaires were employed in collecting primary data for this study.

During the key informant interview session, collection of statements comprising of likely prospects and constraints to the cultivation of GM crops were compiled and presented to the 360 smallholders to rank in order of importance or severity. Descriptive statistical analysis was undertaken to analyse the distribution of respondents' rank scores. Also Kendall's coefficient of concordance was applied to examine the level of agreement among respondents' ranks of the likely prospects and constraints to the cultivation of GM crops. Kendall's Coefficient of Concordance (W) is an index that measures the ratio of the observed variance of the sum of ranks to the maximum possible variance of ranks sum.

The idea behind this index is to find the sum of the ranks for each constraint being ranked and then analyse the variability of this sum (Legendre, 2010). If the rankings are in perfect agreement, the variability among the sums will be a maximum. It is used to assess the degree to which respondents in a study provide common ranking on an issue. Applying preference ranking, the total rank score for each item is computed and *W* calculated. The *W* is calculated using the formulae;

$$W = \frac{12(S)}{m^2(n)(n^2-1) - mT} \quad (3)$$

Where ***n*** is the number of objects, ***m*** is the number of variables and ***T*** is a correction factor, ***S*** is a sum-of-squares statistic over the row sums of ranks R_i, and R is the mean of the R_i values computed first from the row-marginal sums of ranks R_i received by the objects:

$$S = \sum_{i=1}^{n} (R_i - \bar{R})^2 \quad (4)$$

To count for possible tied ranks ***T*** is;

$$T = \sum_{k=1}^{g} t_k^3 - t_k \quad (5)$$

t_k = the number of tied ranks in each (*k*) of g groups of ties. The sum is computed over all groups of ties found in all m variables of the data table. *T*= 0 when there are no tied values and the equation becomes;

$$W = \frac{12(S)}{m^2(n)(n^2-1)} \quad (6)$$

W is an estimate of variance of the row sums of ranks (R_i) divided by the maximum possible value the variance can take; this occurs when all variables are in total agreement. Hence $0 \le W \le 1$; *W* of 1 represents perfect concordance/agreement and 0 indicates perfect disagreement in the ranking. The Friedman's Chi-square statistic (χ^2) was used to test the significance of the *W* obtained.

From Friedman's Chi-square statistic (χ^2) as given by;

$$\chi^2 = m(n-1)W \quad (7)$$

The Chi-square is asymptotically distributed with *(n-1)* degrees of freedom and it used here to test the significance of *W.* However, the data set have to meet reliability test to be sure it is satisfactory for Kendall analysis. The number of raters (n) and the factors (m) being rated should be reasonable large enough to allow for valid interpretation (Legendre, 2010). In this study 360 raters (n = 360) rated 11 factors (m = 11) and it is considered large enough for valid interpretation.

RESULTS AND DISCUSSION

This section presents results of analysis and discussion of data obtained from 360 smallholder farmers surveyed in northern Ghana to assess their perceived prospects and constraints likely to be associated with the cultivation of genetically modified crops.

Farmers' prospects about GM crops

Eleven issues were common among respondents' list of perceived prospects of GM crops cultivation. These issues ranged from breeding drought tolerant crops to improving food security and farm productivity. Frequency distribution of the rank scores is presented in Table 2a. Kendall's coefficient of concordance conducted to determine significance and level of agreement among rank scores assigned to the eleven issues in respondents list of prospects of GM crops cultivation, shows significant agreement at 1% among respondents assigned ranks with Chi-Square (df = 10) = 651.147; Asymp. Sig = 0.000 (Table 2b). Kendall's coefficient of concordance (W) = 0.47 indicates that there is 47% agreement among the respondents' rank scores.

As shown in Table 2a and b, the prospects that GM technology can be used to breed drought tolerant Crop varieties was ranked as the number one prospects with 61% of the 360 respondents ranking it as the most important. The prospects of GM technology being used to breed early maturing and high yielding crop varieties was ranked as the second most important prospect with 31%. The prospect of GM crop cultivation helping to reduce cost of weed control and bringing in high economic returns were respectively ranked as 6th and 4th. In recent time the study area has been experiencing drought and erratic rainfall pattern (MOFA, 2016) making agricultural a high risk venture and less productive. It is therefore understandably that farmers considered drought tolerant and early maturing varieties of crops as the most important.

The prospects of GM technology being used to improve

Table 2a. Respondents' ranks on perceived prospects of GMO technology.

Items	Rank Score																					
	1		2		3		4		5		6		7		8		9		10		11	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Breed drought tolerance Crop varieties	218	61	32	9	16	4	0	0	0	0	15	4.2	16	4	16	4	31	9	0	0	16	4
Breed short maturity/high yielding crop varieties	79	22	110	31	46	13	0	0	0	0	0	0	31	9	0	0	16	4	16	4	62	17
Reduce cost of weed control	0	0	46	13	61	17	80	22	48	13	0	0	0		16	4	16	4	77	21	16	4
Disease/pest resistance varieties of crops	0	0	31	9	64	18	123	34	32	9	16	4	0	0	16	4	47	13	16	4	15	4
Improve nutrition	0	0			30	8	32	9	155	43	80	22			47	13	16	4	0	0	0	0
High economic return			16	4	48	13	30	8	64	18	123	34	63	18	16	4	0	0	0	0	0	0
Reduce labour intensiveness of weed control	15	4	46	13	16	4			46	13	48	13	93	26	16	4	0	0	0	0	80	22
Improve seed viability	0	0	15	4	0	0	32	9	32	9	30	8	31	9	77	21	16	4	80	22	47	13
improve food security	16	4			31	9	32	9	16	4	0	0	30	8	32	9	157	43	31	9	15	4
Reduce environmental risks	16	4	32	9	32	9	15	4	0	0	16	4			109	30	32	9	92	26	16	4
Meet consumer taste	16	4	48	13	16	4	0	0	15	4	0	0	96	27	31	9	45	13	16	4	77	21

Source: Analysis of field survey Data (2016).

Table 2b. Perceived prospects of GM technology.

Items	Mean	SD	Mean rank	Rank
Breed drought tolerance Crop varieties	3.10	3.27	3.10	1st
Breed short maturity/high yielding crop varieties	4.55	3.87	4.58	2nd
Reduce cost of weed control	5.84	3.09	5.93	6th
Disease/pest resistance varieties of crops	5.22	2.63	5.28	3rd
Improve nutrition	5.54	1.50	5.58	5th
High economic return	5.34	1.53	5.39	4th
Reduce labour intensity of weed control	6.57	3.14	6.59	7th
Improve seed viability	7.76	2.49	7.80	11th
improve food security	7.42	2.66	7.44	10th
Reduce environmental risks	7.19	3.05	7.17	9th
Meet consumer taste	7.13	3.20	7.15	8th

N = 360; Chi-Square (df = 10) = 651.147; Asymp. Sig = .000; Kendall's W = 0.47.
Source: Analysis of field survey Data (2016).

food security and seed viability were ranked 10th and 11th respectively and were the least preferred prospects by the 360 respondents. This implies that respondents do not attach much importance to the fact that GM technology can be used to improve seed viability and food security situation.

This is contrarily to the findings of Ademola et al. (2014) which concluded and Nigeria. It could be that the farmers surveyed failed to link high yielding and drought tolerant crop varieties to food production and hence food availability and food that food security is topmost potential benefit of biotechnology in West Africa, particularly Ghana security. Because it is strange that they ranked the prospect of GMOs technology enabling scientist to breed drought tolerant and early maturing crops varieties as the most important but rather ranking its contribution to food security as the least important. Because it is to be expected that by implication if crops are tolerant to drought and early maturing crops loses to drought would be reduced and hence more yield and food availability.

In general, respondents have much hope on GM technology being used to breed drought tolerant, early maturing and high yielding local crop varieties and help reduce cost of weed, pest and disease control. At the various focus group discussions participants expressed similar positive expectations of GM crops with relevant traits and how they hope the GM technology could be used to improve on their local crop varieties. Also possibility of reduce cost of production through reduction in weed control and other plant protection practices were highlighted in the various focus groups discussions and the key informant interviews. A key informant interviewed in the Kasena/Nankana East District stated:

"*I heard that this new crop when grown in the field can be sprayed with roundup weedicide to kill all weeds without affecting the crops ….. and this makes me very much interested in it …. I will grow them when I get the seeds. With the new crop, I can increase my crop yield because weed infestation is my major problem* ..." (Key informant interview, Kaena/Nankana East District, Ghana, August, 2016).

Another key informant in the Bolgatanga Municipality said:

'*if GM crops are high yielding and can withstand roundup chemical, as they claimed in the radio, then cultivating it will make us gain more yield* …' (Key informant interview, Bolgatanga Municipality, Ghana, August, 2016).

This finding confirms previous studies which stated that GM technology holds many prospects for Africa smallholder farmers. Mwamahonje and Mrosso (2016) in their study on 'Prospects of genetically modified maize crop in Africa' concluded that GM maize with its high yielding and drought tolerant traits hold much prospects for improving food security in Africa. Also, Barrows et al. (2014) in their study on 'Agricultural biotechnology: The Promise and Prospects of Genetically Modified Crops' identified insect resistance and herbicide tolerant as the most popular and promising GM crops traits.

Farmers' perceived constraints to the cultivation of GM crops

Table 3a and b present results of analysis of respondents' perceived constraints towards GM crop cultivation. Eleven common issues identified by respondents as possible constraints to the cultivation of GM crops were analysed using Kendall's coefficient of concordance. The issues identified as possible constraints include high cost of GM seed, unreliable supply of GM seed, possible failure of regulatory agencies and possible environmental and health risks among others. Results of Kendall's coefficient of concordance established significant agreement among respondents' ranked scores of their perceived constraints to the cultivation of GM crops. As shown in Table 3b, the Chi-Square (df = 10) = 936.664; p-value = 0.00 thus indicate significant agreement among respondents ranked scores at 1% level of significant. A Kendall's co-efficient of concordance (W) = 0.60, implies that 60% of the ranked scores assigned by respondents agree.

Analysis of the distribution of the ranked scores with 1 as the most severe constraints and 11 the least severe constraints shows that high cost of GM seed is perceived by respondents as the most severe constraint to the cultivation of GM crops with 50% of the respondents ranking it as the topmost severe constraint. This was followed by possibility of unreliable GM seed supply which comes as the second most severe constraint perceived by respondents towards the cultivation of GM crops. Fear of possible environmental risks and failure of regulatory agencies were ranked as the third and fourth most severe constrain to the cultivation of GM crops respectively.

This clearly demonstrates that cost of GM seeds and unreliability of its supply are the biggest concerns respondents have regarding GM crops cultivation. They are obviously worried that they might not be able to benefit from the commercialization of GM crops because of the possibly high cost involve in obtaining GM seeds. Participants at the various focus group discussions sessions expressed concerns about possible high cost of GM seeds and unreliability of its supply should they adopt the cultivation of GM crops. A key informant expressed the following concern;

'*This new crop seeds, can we buy the seeds?, I hear they are very expensive and how sure are we that we they would supply us the seeds at the time we need them and will they even be good ones*'(Key informant interview, Savelugu/Nanton Municipality, Northern Ghana, October, 2016).

Another respondent expressed health and environment

Table 3a. Perceived constraints of GMO technology.

Items	Rank score																					
	1		2		3		4		5		6		7		8		9		10		11	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
High cost of GM seed	181	50	54	15	0	0	36	10.	0	0	17	5	18	5	18	5	18	5	0	0	18	5
Unreliable supply of GM seed	72	20	72	20	54	15	53	15	18	5	18	5	19	5	18	5	18	5	0	0	18	5
Possible failure of regularity agencies	18	5	90	25	54	15	90	25	17	5	19	5	18	5	18	5	18	5	18	5	0	0
Possible environmental risk	18	5	54	15	125	35	72	20	19	5	18	5	18	5	0	0	18	5	18	5	0	0
Possible health risks	0	0	17	5	0	0	18	5	144	40	54	15	18	5	37	10	18	5	18	5	36	10
possible destruction of local seeds	0	0	0	0	0	0	0	0	108	30	90	25	53	145	18	5	37	10	36	10	18	5
Dependence on GM company	0	0	0	0	0	0	36	10	0	0	90	25	108	30	35	10	36	10	18	5	37	10
Possible consumer rejection	18	5	0	0	18	5	0	0	18	5	18	5	54	15	144	40	17	5	37	10	36	10
Possible emergency of super weeds and bugs	0	0	73	20	0	0	18	5	0	0	36	10	54	15	18	5	72	20	71	20	18	5
Possible labelling conflict and coexistence with convention crops	0	0	0	0	54	15	19	5	36	10	18	5	0	0	18	5	72	20	90	25	53	15
Incompatibility with smallholder farming system	17	5	18	5	55	15	36	10	18	5	18	5	0	0	36	10	18	5	54	15	90	25

Source: Analysis of field survey Data (2016).

Table 3b. Ranks of perceived constraints to GM crops cultivation.

Items	Mean	SD	Mean rank	Rank
High cost of GM seed	3.24	3.12	3.34	1st
Unreliable supply of GM seed	4.00	2.83	4.05	2nd
Possible failure of regularity agencies	4.25	2.47	4.30	4th
Possible environmental risk	4.05	2.27	4.06	3rd
Possible health risks	6.42	2.32	6.39	5th
possible destruction of local seeds	6.91	1.90	7.01	7th
Dependence on GM company	7.31	1.91	7.43	9th
Possible consumer rejection	7.55	2.38	7.55	10th
Possible emergency of superweeds and bugs	6.98	3.01	6.90	6th
Possible labelling conflict and coexistence with convention crops	7.78	2.86	7.81	11th
Incompatibility with smallholder farming system	7.05	3.50	7.16	8th

N = 360; Chi-Square (df = 10) = 936.664; Asymp. Sig = .000; Kendall's $W^{=}$ = 0 .60.
Source: Analysis of field survey Data (2016).

concerns about the cultivation of GM crops as:

''*I heard on radio the other time that this new crop is not good for the environment and it poisons slowly when eaten*…'' (Personal interview, Upper West region, Ghana, August, 2016).

Possible high cost of GM seeds was strongly highlighted in many of the focus group discussions and the key informants interviews conducted. Some of them proposed some suggestions to dealing with the possible high cost of GM seeds. One key informant in the West Mamprusi District proposed that"

'*I heard that in Burkina Faso tomato and cotton farmers are given GM seeds free, so if Ghana government can do that then we will try these new crops.*'' (Key informant interview, West Mamprusi District, Northern Ghana, November, 2016).

Another participant in the Bolgatanga Municipality also expressed fear about the possible high cost of GM seeds as"

''*we are told that these GM seeds are produced overseas, so when they bring them here they will be very expensive, besides we cannot reproduce them and use, because they have killed their soul and they cannot be replanted …. meaning we have to always import the seeds from overseas every year*..'' (Key informant interview, Bolgatanga Municipality, Northern Ghana, August, 2016).

Suggesting possible solution to the likely high cost of GM seed a key informant in the Gushiegu District proposed that;

''*to deal with the high cost of this new crop seeds, why can't Ghana government do like what Burkina Faso government is doing for their tomato farmers, where the government buys GM tomato (sweet flavour) seed from overseas and distribute to farmers free* ..'' (Key informant interview, Bolgatanga Municipality, Northern Ghana, November, 2016).

CONCLUSION AND RECOMMENDATIONS

In general, respondents have much hope on GM technology being used to breed drought tolerant, early maturing and high yielding local crop varieties and help reduce cost of weed, pest and disease control.

Issues identified as possible constraints to the cultivation of GM crops from the perspectives of smallholder farmers surveyed include high cost of GM seed, unreliable supply of GM seed, possible failure of regulatory agencies and possible environmental and health risks among others. However, the cost of GM seed and the unreliability of its supply were ranked as the most important constraints regarding GM crops cultivation.

Efforts should be made by the Ministry of Food and Agriculture (MOFA), National Biosafety Authority (NBA), Ghana Seed Inspection Division and other relevant organizations to address farmers' concerns and reservations regarding possible high cost of GM seeds, the fear that GM seed supply might not be reliable and possible health and environmental risks associated with the cultivation of GM crops. Also public and outdoor campaigns aimed at providing information to address these concerns of farmers should be designed and implemented through the mass media by MOFA, NBA and Open Forum for African Biotechnology (OFAB), and other relevant NGOs and private organizations. The possibility of GM seed subsidy and Public Private Partnership strategies with biotech companies should be explored by MOFA and NBA to help reduce cost of GM seeds for smallholder farmers. Farmers' expectations on GM technology being used to improve local varieties through breeding of drought and herbicide tolerant, and insecticide resistant varieties of local staple crops, as uncovered in this study, should be given attention by Ghanaian research institution particularly the Savannah Agricultural Research Institution (SARI) and Crop Research Institute (CRI).

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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