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Knowledge and understanding about genetically modified (GM) crops among smallholder farmers in Northern Ghana

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Ghana had made steady progress towards the commercialization of Genetically Modified (GM) crops amidst mounting opposition. This paper presents findings of an empirical study on smallholder farmers' knowledge and understanding of GM crops. Data used in this study was sourced from a survey conducted among members of Farmer Based Organizations (FBOs) in Northern Ghana in which 120 FBOs across 10 districts in the then three northern regions: Northern, Upper East, and Upper West regions were sampled through a multi-stage sampling technique. Personal and key informant interviews and Focus Group Discussions (FGD) were employed in collecting data for the study. Descriptive statistics and discourse analysis were employed in analyzing the data gathered from the survey. Analysis of respondents' narratives on GM crops revealed a wide array of ideas ranging from factual, partly factual, mystical to a fictitious understanding about GM crops. In general, what smallholder farmers in northern Ghana know and understand about GM crops can be described as patchy and vague. The study found a significant relationship ($\chi 2 = 29.565$; df = 2; P>| $\chi 2$ | = 0.004) between the source of information on GM crops and the accuracy of farmers' knowledge and understanding about GM crops. It is therefore recommended that National Biosafety Authority (NBA) should strengthen their public education on GM crops and Ghana's agricultural biotechnology policy.

Key words: Knowledge, genetically modified (GM) crops, biosafety, Northern Ghana, agro biotechnology, smallholder farmers.

INTRODUCTION

Notwithstanding the raging debate about Genetically Modified (GM) crops, since its commercial release in 1996, global production of this novel crops technology continues to increase at progressive rate annually (Brookes and Barfoot, 2019; ISAAA, 2018). Within its two and half decades of commercialization, GM crops,

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particularly, *Bacillus thurigiensis* (Bt) cotton and maize, canola, GM soybeans and golden rice, have spread across over 25 countries, both developed and developing nations, and has been adopted by large and small-scale farmers alike (Brookes and Barfoot, 2019; ISAAA, 2019). Millions of small and large-scale farmers who have adopted the cultivation of GM crops worldwide are repeating its planting. This demonstrates farmers' confidence and approval of the technology. The leading world producers of GM crops are the United States (US) and Brazil, followed by Argentina, India, Canada, China and South Africa (ISAAA, 2018).

However, few countries in Africa namely South Africa, Burkina Faso, Egypt, and Sudan have fully adopted commercial production of GM crops. Though, in recent times, only South Africa and Sudan in the African continent planted GM crops in 2016 (Brookes and Barfoot, 2019). South Africa as the leading producer of GM crops in Africa and among the top ten countries in the World cultivated more than 1 million hectares of GM crops in 2016 (ISAAA, 2016). The newest entrance, Kingdom of eSwatini (formerly Swaziland), planted Bt cotton in 2018 while Burkina Faso and Egypt have placed temporary moratorium on the production of GM crops in 2018 (Brookes and Barfoot, 2019; ISAAA, 2019).

However, in terms of policy direction, many African countries have made appreciably progress towards commercial production of GM crops by way of biotechnology research, enactment of legally binding biosafety regulations and institutional frameworks necessary for commercial production, handling and use of GM products. Noticeably, among the progress made is the approval and release of Bt cotton, soybean and canola seeds for commercial production in Egypt, Sudan and Kenya (ISAAA, 2019; Tarjem, 2017).

Ghana had not been left out in the progress made towards commercialization of GM crops in Africa. The country had established the necessary legal regulatory and institutional frameworks required in ensuring biosafety standards and safety production, handling and use of biotechnology products. Ghana's Biosafety Act (Act 831) which was passed and ascended into law in 2011, layout the necessary, legal regulatory and institutional frameworks, in line with international standard and protocols, to guide research, commercial production and use of biotechnology products (Braimah et al., 2017; et al., 2016).

In terms of research, Ghana's Savannah Agricultural Research Institute (SARI), one of the thirteen (13) research institutes of the Council for Scientific and Industrial Research (CSIR), located in Northern Ghana with the mandate of providing farmers in that part of the country with appropriate technologies to increase their food and fibre crop production based on a sustainable production system, had within the last five years made progress in commercial production and release of GM crops. SARI researchers have been conducting field trials and contained release pending commercialization of Bt cotton, soybean and cowpea (Agorsor et al., 2016; Braimah et al., 2017)

Notwithstanding the fact that awareness and knowledge about a technology is critical in its adoption as demonstrated in Rogers' innovation diffusion theory (Rogers, 2003) very little is known by way of empirical research on Ghanaian smallholder farmers' knowledge and understanding about this novel crop technology. Essentially, Rogers' (2003) innovation diffusion theory explained that adoption is process that goes through several stages including understanding, persuasion, decision, implementation, and confirmation (Lai, 2017). This knowledge gap is particularly critical because overwhelming majority (80%) of crop farmers in Ghana are smallholders operating less 2 ha of farmlands with poor access to extension services and modern technologies (MOFA, 2016).

There is therefore a void regarding source of information on GM crops available to smallholder farmers in Ghana and the knowledge farmers have about GM crops. This is critical because according to Rogers (2003) and Ajzen (2006) knowledge and information about a technology influence farmers' perceptions, attitudes and final adoption decision.

However, available studies which examined Ghanaian farmers' views on GMOs often failed to assess their knowledge and understanding about this novel crop technology. A study by Ademola et al. (2014) on potential benefits of biotechnology on food security in West Africa, identified challenges such as lack of awareness, inadequate training, low level of education and poor extension services among others as the main challenges facing the introduction of GM technology among smallholder farmers in Ghana and Nigeria. Also, Zakaria et al. (2020) found source of information on GM crop as a significant driver of smallholder farmers' adoption decision. To bridge this knowledge gap, this paper presents findings of a study which examined smallholder farmers in Northern Ghana knowledge and understanding about GM crops.

METHODOLOGY

Study area

The study was conducted in Northern Ghana, comprising the then three northernmost administrative regions, namely, Northern, Upper East and Upper West regions. However, currently two additional regions have been curved out of the then northern region and this happened after the survey in 2016. This part of the country lies in the Savannah Ecological Zone (SEZ) which is characterised by poor fragile soils with erratic climatic conditions and with one rainy season spanning from late March to October every year (MOFA, 2011). The NSEZ is the poorest area in the country where food insecurity and endemic poverty characterised the lives of many people in the area (GSS, 2017). Poverty in this ecological zone is most severe among food crop farmers, who are mainly traditional rural small-scale producers (ibid).

Research design

Descriptive survey design was employed in carrying out this study as the objective was to explore and describe farmers' knowledge about GM crops. Descriptive survey research design is the 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 al., 2003).

Sample size determination and sampling procedure

Cochran's (1977) sample size determination formula was employed in calculating the sample size used in the 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 FBOs in the Northern Ghana, and 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, the sample size was determined as:

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

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 (3) members who have ever heard and/or read about GM crops were purposively selected to bring the total sample size to 360 smallholder farmers.

Multi-stage sampling procedures were adopted in selecting respondents for the study. The first stage was stratified random sampling in which the study area was stratified into three strata, with each region being a stratum. This was followed by simple random sampling of districts from each region based on proportional representation. The third stage was purposive sampling technique where crop based FBOs and members of FBOs who have ever heard and/or read about GM crops were purposively selected.

Only districts with registered FBOs with contact details 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. FBOs within each of the sampled districts were sampled using lottery method of simple random sampling technique. With northern region constituting about half of the total FBOs in the three regions, and based on proportional representation, five (5) districts were sampled from Northern region, while three (3) and two (2) districts, respectively from Upper East and Upper West regions making a total of ten (10) sample districts. 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 Northern region.

Based on proportional representation 74, 28 and 18 FBOs were sampled from northern, upper east and upper west regions, respectively. Among members of the sampled FBOs in the 10 districts 222, 84 and 54 smallholder farmers who have ever heard and/read about GM crops were respectively selected from northern, upper east and upper west regions.

Data collection and analysis

Five focus group discussions were conducted among smallholder farmers in the sampled districts with an average of 9 participants per focus group discussion. In addition, in-depth interviews prior to the actual field survey were conducted with thirteen (13) key informants comprising ten (10) leaders of FBOs and three (3) commercial farmers across the three regions. Also, personal interviews facilitated by interview guide and aided by interpreters were used to interview the 360 smallholder farmers sampled across the 10 sampled districts. Through this process both qualitative and quantitative data were collected for this study.

Both quantitative and qualitative analytical techniques were employed in analysing data collected in the survey. The study employed mixed methodological process of studying narratives, discourse, viewpoints and perceptions. For the qualitative data gathered from the focus group discussions and in-depth interviews, content analytical techniques with open coding and aided by F4 analyse software were employed in identifying main and sub themes portraying respondents' knowledge about GM.

Content analysis is a widely used qualitative research technique. The applications of content analysis show three distinct approaches namely conventional, directed, or summative. All three approaches are used to interpret meaning from the content of text data and, hence, adhere to the naturalistic paradigm (Hsieh and Shannon, 2005).

The major differences among the approaches are coding schemes, origins of codes, and threats to trustworthiness. In conventional content analysis, coding categories are derived directly from the text data. As such this study applied conventional content analysis with open and direct coding procedure.

Analysis of the qualitative data began with open coding system, where transcribed narratives obtained from focus group discussions and in-depth interviews were broken down into smaller parts. That is, all data obtained from qualitative research questions were closely examined for categories, main themes and sub-themes.

RESULTS AND DISCUSSION

Notwithstanding the fact that commercialization of GM crops began some two decades ago and had attracted media attention and public concerns, information and knowledge about GM crops among farmers and consumers in Ghana is still very limited.

Therefore, the criteria for selecting respondents of this study were that they must have been members of FBO and must have heard and/or read about GM crops. As a result of these selection criteria, many FBOs whose details were obtained from MOFA districts offices in the study areas were not selected because their members have never heard and/or read about GM crops. This was indicative of the fact that knowledge and information about GM crops among farmers in the study area were very limited. This was to be expected because Ghana is yet to start commercialization of GM crops even though biosafety legislative, institutional and policy frameworks are far advanced (Agorsor et al., 2016; Braimah et al.,

2017).

Source of information on GM crops

As indicated in Figure 1, the various sources of information about GM crops among respondents were extension officers, colleague farmers/friends/relatives, radio/TV and other mass media and traders/input dealers.

Many (43%) of the smallholder farmers interviewed, first heard of GM crops on radio, television and other mass media, while close to a third (29%) first heard of GM crops from their colleague farmers, friends or relatives. However, only 10% of the respondents mentioned extension officers as their first source of information about GM crops, while 18% said they first heard of GM crops from input dealers and/or traders.

Information gathered among participants in the various focus group discussions held regarding their source of information about GM crops revealed that, information on GM crops was being constantly broadcast at the various local FM stations by anti–GM crops activists campaigning against commercialization of GM crops in Ghana and the passage of the 'Plant Breeders' Protection Bill', which has been in Ghanaian parliament for many years without being passed into law.

Participants explained that during the period of the anti–GM crops campaigns, many local FM stations and other airwaves were inundated by activists who spread all kinds of information about GM crops and called on peasant farmers to join the campaign. This was vividly illustrated by a key informant:

''*all what I know about GM crops are what the people said when they were discussing it at the FM station, I don't know whether to believe it or not, but if what they say is true then the Whiteman is challenging God*'' (Key Informant Interview, Northern region Ghana, August, 2016).

The campaign, which was led jointly by Food Sovereignty Ghana, Faith-Based Organizations, Action Aid Ghana, Centre for Indigenous Knowledge and Organizational Development and Peasant Farmers Association of Ghana under the banner 'National Campaign Against Plant Breeders' Bill' was against Ghana's possible adoption of biotechnology in agricultural production and the passage of 'plant breeders' protection bill.

Similar findings of smallholder farmers sourcing their information on GM crops from the mass media had previously been established in Zakaria (2020), Hall, (2010), Kennet (2011) and Yawson et al. (2008).

They established that the mass media is the main source of information on GM crops and food.

Vigani and Olper (2013) also found that the mass media drive and shape public views and perceptions towards GM crops because it is the main source of information on GM crops to most people.

Farmers' knowledge and understanding of GM crop

Analysis of narratives gathered at the various focus group discussions regarding participants' knowledge on GM crops demonstrated a diverse understanding of what GM crops are. These varying views and knowledge about GM crops range from general knowledge to wild, absurd and mythical understanding of GM crops. Sieving through the narratives of participants' descriptions of what they know about GM crops, the following themes were extracted:

(1) GM crops are artificially bred crops.
(2) Seeds from GMOs are sterilised.
(3) GM crops are bred to be herbicide tolerant.
(4) GM crops are crops injected with chemical to boost their performance.
(5) GM crops are crops impregnated with seeds/genes of other organisms to have dual performance.

GM crops are artificially bred crops

Some of the participants at the various focus group discussions understood GM crops as crops artificially bred through man made manipulation of the nature of the affected crops to enhance their performance. These crops are usually high yielding and their produce has long shelf life as observed by participants. This knowledge of GM crops as understood by farmers does not deviate so much from the definition of genetic engineering through which GM crops are produced. According to Global Food Security (CSIS, 2010) genetic engineering allowed scientists to adjust, modify or alter the genomes of target organisms for improved performance and much desired results. It involves some level of manipulation, altering and modification of naturally occurring living organisms to produce new breed of organisms that might exhibit traits which differ from the original organism.

Seeds from GMOs are sterile

Another understanding of GM crop from the perspective of participants at the various focus group discussions was that GM crops seeds are sterilised and cannot be replanted. According to their understanding, a farmer cannot select seeds from his/her harvested GM crops and replant the next season, which is a common practice among farmers in the study area but must go back to the producers and buy the seeds again. In response to further probe on why GM crops seeds selected from farmers' own harvest cannot be replanted as they claimed, a key informant explained:

'The *scientists who developed GMOs seeds deliberately*

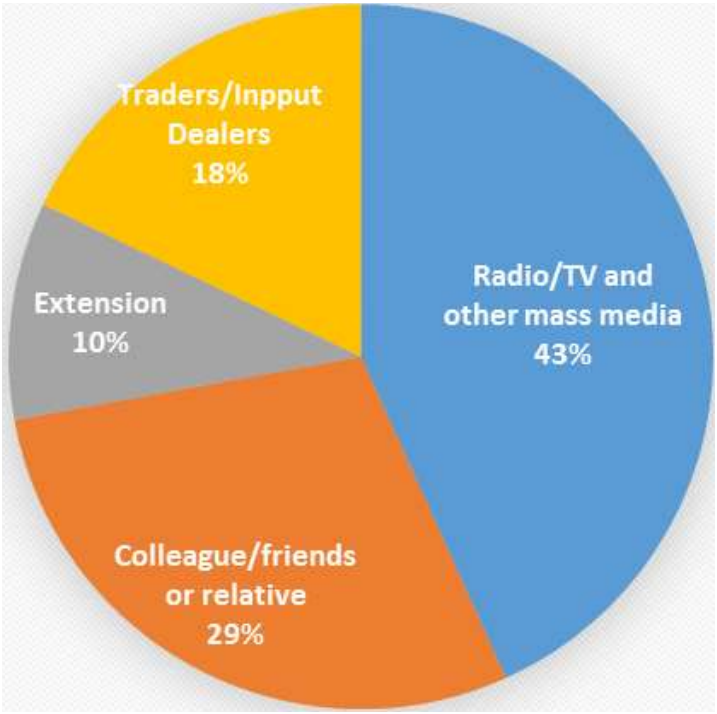

Figure 1. Respondents' source of information on GM crops.
Source: Analysis of Field Survey Data (2016).

sterilised them so that farmers will always have to come to them for seeds' (Key informant interview, Kasena/ Nankana East District, Upper East region, Ghana, November, 2016).

Also, a key informant again at the Upper East region claimed that:

"*these people want to replace our seeds with their sterilised seeds so that we will always have to purchase our seeds from them, so they can make more money from us poor farmers*" (key informant interview, upper west region, Ghana, August, 2016).

Such statements and reservations were echoed in many of the focus group discussions held.

This understanding of GM crops as indicated by respondents has some scientific basis because many of the GM crops grown are "hybrids" and as a result do not breed true and there is high possibility of degeneration in successive generation. Not breeding true means that the next crop will not look the same as the previous one. However, to argued that GMOs seeds are deliberately sterilised to prevent farmers from replanting after harvest is mythical and fallacious. However, there are regularity regime by way of intellectual property right and breeders' protection legislatures to protect the investment on GMOs seeds development.

As a result, GM seeds are licensed and covered by intellectual property right which requires farmers to obtained permission from corporate or individual entities holding the right to the GM seeds before they can use it (Specter, 2014; Fukuda-Parr and Orr, 2012).

The issue of patents rights covering GMOs seeds has been a long-standing criticism against the commercialization of GM crops in developing countries as observed by Zakaria (2020). Similarly, Leonelli (2019) study on the dominant regulatory approach to the governance of GMO risks argued that although GMOs are identified as a strategy to tackling food insecurity and facilitating climate change adaptation, the patents and trade regime of GM seeds serve the profit-making goals of transnational market actors.

This fear and scepticisms by respondents regarding re-use of GMOs seeds for planting have been the concerns of many anti-GMOs activists. Katiraee (2014) observed that the common criticism of genetically modified foods is that their seeds are patented to developers who are mostly profit motivated multinational corporations. This phenomenon is known to peasant farmers who traditionally, select part of their harvest and store them as seed for the next season, and practice plant improvement by selecting and exchanging seeds with one another (Etwire et al., 2013).

GM crops are bred to be herbicide tolerant

Another theme characterising participants' understanding

of GM crops is about the Round-up Ready (RR) traits of GM crops which are bred to be glyphosate tolerant. Participants indicated that, what they heard is that, GM crops can withstand all herbicides including non–selective round-up herbicides. They were also of the opinion that all GM crops carry this trait of tolerant to glyphosate herbicide.

Notwithstanding the fact that not all GM crops carried the glyphosate resistance trait, participants were right to some extent that GM crops are bred to be tolerant to herbicides because GM crops carrying the traits for glyphosate resistance is one of the common GM crops commercially produced globally. The most commercialised varieties of GM crops released for production carries traits such as herbicide resistance (Round-up Ready (RR)) and insect resistant Bt crops and few crops such as golden rice fortified for improved nutrition (Adenle, 2011; Brookes and Barfoot, 2019; Brookes and Barfoot, 2018; James, 2014; ISAAA, 2016).

Analysis of narratives gathered from participants in the various focus discussions indicates that participants are very much aware of the glyphosate resistant traits of GM crops.

They indicate that such crops will help them deal with the problem of weed control which they indicated will help boost crop production.

"*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, Northern region, Ghana August, 2016).

This view was widely shared among many of the participants of the five focus group discussions held.

GM crops are crops injected with chemical to boost their performance

One other opinion about GM crops gathered from the narratives of participants at the various focus group discussions is that GM crops are produced by injecting chemical into plants by scientists to boost their performance. They argued that, it is the chemical that makes GM crops possess the desired traits of high yielding, glyphosate tolerant and long shelf life among others. In response to a further probe on based on such claim that GM crops contained chemical, a respondent said:

"*I saw this Whiteman injecting chemical into tomato plant myself on TV.* …" (Key informant interview, Upper west region, September, 2016).

Another respondent in expatiating on this claim, said: "*just like how they have injection which can make human being grow fat and fast, there are injections too for plants and this is what they have done to this new plant*" (key informant interview, upper east region, November, 2016).

These are obvious misconceptions and untruths about the process of producing GM crops which can affect farmers' perception and attitude towards GM crops. Such mystical and mental constructed views about GM crops are created by ant-GM activist and driven through mass media with visual effects. Zakaria (2020) argued that many of the fears and concerns about GM crops are borne out of overhyped, speculative and fear-mongering information churned out mainly in mass media by anti-GM activists. Also, Raman (2017) in his study about construction of utopian and apocalyptic narratives in social movement campaigns and how they contribute to the construction of identities in the campaigns against GM food and Bt cotton in India and concluded that "organic food" and "ethical cotton" products would be less successful without the concurrent use of apocalyptic narratives on media about GM food and Bt cotton.

GM crops are crops impregnated with seeds/genes of other organisms to have dual performance

One opinion and understanding of GM crops from the narratives of participants at the various focus group discussion, is the impression that GM crops are produced from fusion of two or more organisms to producing one organism. According to the participants, GM crops exhibit dual attributes by showing traits of both organisms fused together.

This understanding of GMOs can be likened to gene insertion and manipulation through the process of genetic engineering.

Further probing revealed that most of the participants are referring to hybrid plants, judging from their description of the process of the said fusion they claimed is used in the development of GM crops.

One of the respondents during personal interview session said:

"*you see what they do. They will bring for instance yellow maize and fuse it with white maize to produce a new maize variety which has the taste of both yellow and white maize and yield more than both yellow and white maize varieties*…." (Personal interview, Upper East region, September, 2016).

This clearly illustrates the process of crossbreeding leading to the generation of hybrid crops. Hybrid plants are nothing more than plants that have been successfully cross-bred with different varieties of plants to take advantage of certain traits and get rid of other less advantageous traits, and this has nothing to do with

genetic engineering. When two dissimilar varieties are crossed, the result is a hybrid which will often be bigger, brighter, faster-growing or higher-yielding than either of its parents. While hybrid technology is limited to crossbreeding within the same plant species, GMOs technology permits crossbreeding between plants of different species. There is therefore apparent misconception among respondents about the differences between GM crops and hybrid crops.

Analysis of responses gathered from the 360 personal interviews conducted among members of FBOs surveyed, to the question "what do you know about GM crops?" reflects the views obtained from the focus group discussions. The analysis of narratives expressed by respondents also fall within the five main themes extracted from the information gathered from the various focus group discussions. While some respondents' narratives on their knowledge about GM crops spread across all the five main themes, others only covered four, three, and two or just one.

Analysis of the main ideas expressed by the 360 respondents about GM crops as shown in the Figure 2 reveals that overwhelming majority of the respondents share the view that 'seeds from GMOs are sterilised' (85%) and that 'GM crops are bred to be resistant to all herbicides' (81.7%). The opinions of about two-thirds of the 360 respondents interviewed support the claim that 'GM crops are artificially bred crops', while more than half (52.5%) and a little under half (47.6%) of the respondents' knowledge about GM crops, respectively support the claims 'GM crops are impregnated with seeds/genes of other organism' and 'GM crops are crops injected with chemical to boost their performance'.

This clearly illustrates that these five main themes identified as characterising smallholder farmers knowledge about GM crops is widely shared among respondents interviewed. Information gathered from the focus group discussions and personal interviews point to the fact that five main themes identified portrayed and represents smallholder farmers in northern Ghana knowledge about GM crops.

Accuracy of respondents' knowledge of GM crops

Analysis of narratives of respondents' knowledge and understanding about GM crops revealed an array of issues ranging from factual information, partly factual, misconceptions, fictitious and mythical. During the focus group discussions, key informant interviews and personal interviews conducted, respondents were asked an open-ended question 'what do you know about GM crops?' and they were allowed to express themselves with some further probes for clarifications.

Analysis of responses to this question revealed that 17.5% of the respondents gave accurate and factual information about GM crops and GMO technology and they are labelled as 'wholly factual'. Other (15.3%) respondents' accounts of GM crops were not entirely accurate because they contained some incorrect information and as such are labelled as 'partly factual' (Figure 3). In all, about a third (32.8%) of the respondents provided either wholly factual or partly factual information about GM crops. Respondents who provided wholly factual accounts of GM crops mentioned or alluded to one or more of the following statements:

(1) GM crops are produced from manipulating existing crop varieties for improve performance.
(2) GM crops are produce from artificially inserting desired parts of plant (genes) into other plants to transfer the traits of one plant to the others.
(3) GM crops can be bred to be resistant to glyphosate (herbicide).
(4) GM crops contain genes of other plants or varieties and as such can behave like them.
(5) Examples of GM crops are Bt cotton and cowpea.
(6) GM food are not much different from their non-GM counterparts.

These statements largely represented accurate accounts of GM crops and GMOs technology. Responses from more than a quarter (26.4%) respondents were made of fabricated and made-up statements about GM crops and therefore their understanding of GM crops was labelled as 'wholly fictitious'. The following are statements made by or alluded to by this category of respondents:

(1) GM crops are produced by injecting chemical onto plants to enhance their performance.
(2) GM crops are farm in laboratories and cannot be grown in open fields.
(3) GM crops are artificially produced or manufactured crops.
(4) GM food are produced for animal consumption only
(5) GM crops contains animal parts in them to give more protein.
(6) The western world doesn't eat GM food they grow them to be shipped to Africa as food aid.
(7) GM seeds after harvesting cannot be replanted, because they will change to something else when replanted.

It is clear that the aforementioned statements do not give accurate accounts of GM crops. The account of other respondents about GM crops was generally about hybrid crops and they are labelled as having 'misconstrued' view about GM crops. In other words they have misconstrued hybrid crops for GM crops. About 9% of the respondents fall into this category. Finally, about a quarter (23.6%) of the respondents provided narratives, some of which fit hybrid crops and others reflect that of GM crops. The account of this group of respondents were a mixture of two or more of the categories mentioned and they are

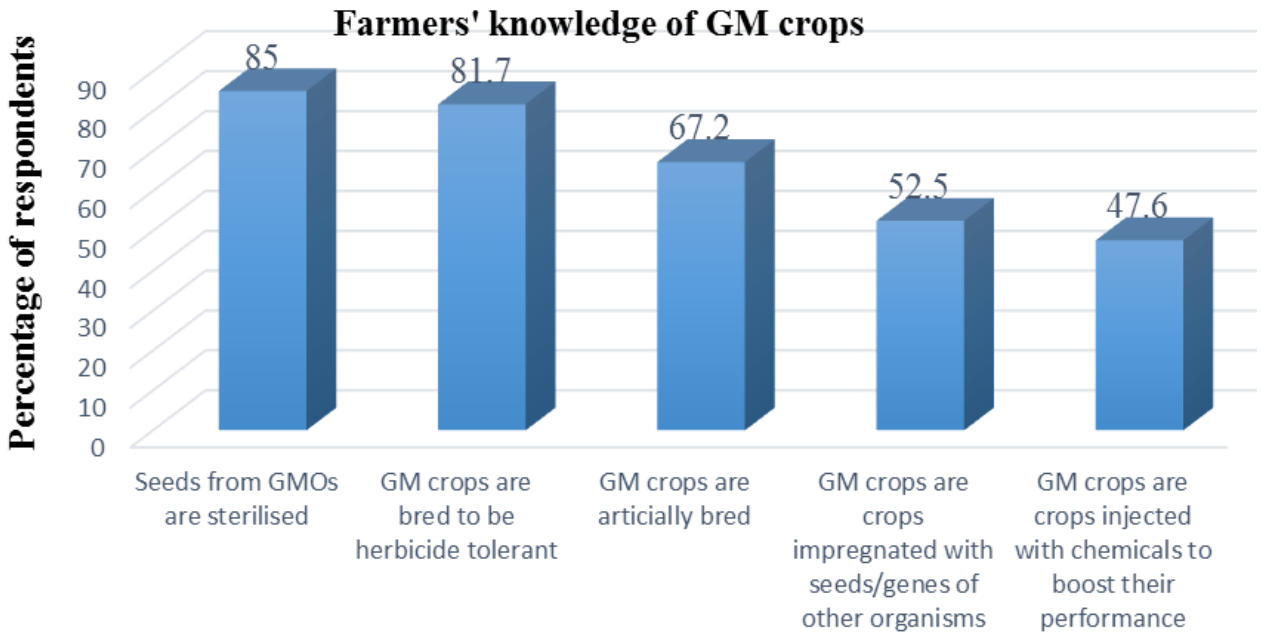

Figure 2. Bar graph showing respondents knowledge about GM crops.
Source: Analysis of Field Survey Data (2016).

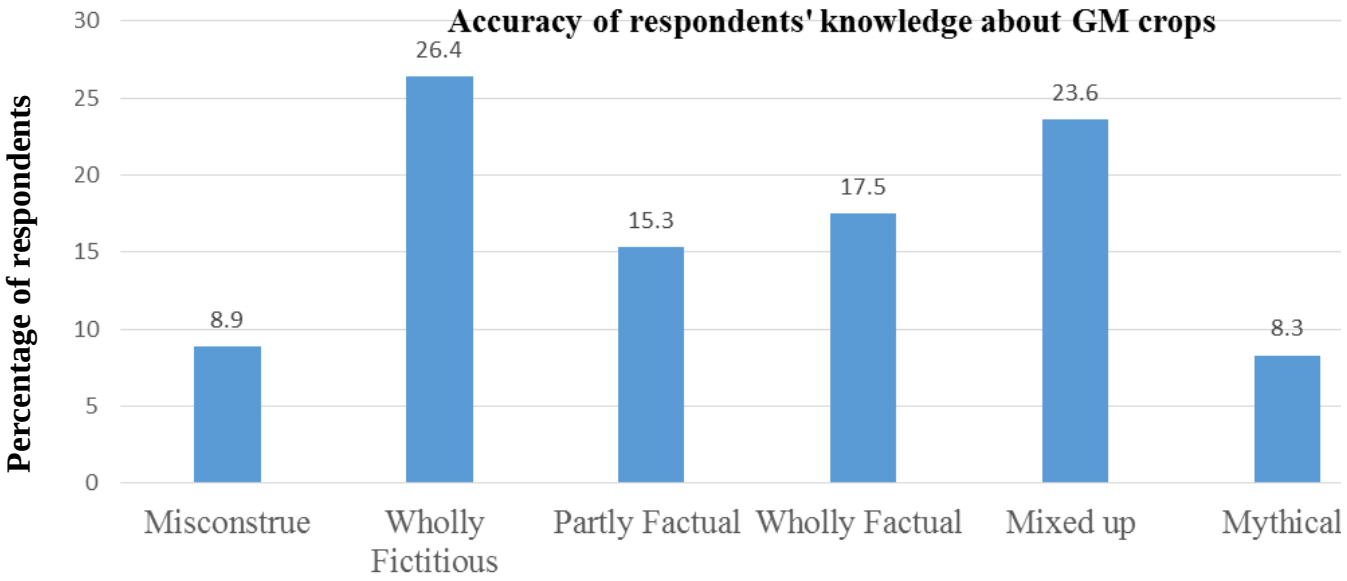

Figure 3. Distribution of the level of accuracy farmers' knowledge on GM crops.
Source: Analysis of Field Survey Data (2016).

labelled as having 'mixed' knowledge about GM crops.

In addition, other respondents provided fairy-tale accounts of GM crops, alluding to issues bordering on myths and fallacies. As such these respondents are labelled as having mythical understanding about GM crops. Some of their accounts of GM crops were to the effect that:

(1) GM crops are crops whose natural purity have been corrupted by scientists to alter their performance.
(2) GM crops are like biblical angels who came down onto the earth, against the command of God, and defiled the daughters of man.
(3) GMO technologies are sacrilegious and acts of aggression against God and sanctity of creation.

(4) GM crops are produced through Whiteman witchcraft which are whispered upon plants to change their forms.
(5) GM crops are not natural as they can transform themselves anytime.

Source of information and accuracy of knowledge about GM crops

In assessing the extent to which respondents' source of information significantly influences the accuracy of their knowledge and understanding on GM crops, a cross tabulation of source of information and accuracy of respondents' knowledge on GM crops shown in Table 1 was constructed and Chi-square test conducted. This was done to test the hypothesis that:

Null hypothesis (H_0): There is no significant relationship between source of information on GM crops and accuracy of respondents' knowledge about GM crop.

Alternative hypothesis (H_a): There is significant relationship between source of information on GM crops and accuracy of respondents' knowledge about GM crop.

As shown in Table 1, the Chi-square (χ^2) value of 17.282 (df = 5; P>| χ^2| = 0.004) means that there is statistically significant relationship (at less than 1% level of significance) between source of information on GM crops and accuracy of respondents' knowledge about GM crops. Thus, the null hypothesis (H_0) is rejected in favour of the alternative. This implies that respondents' main source of information (either from mass media such as radio and TV or other sources such as friends, colleagues, extension officers, agro-input dealers) on GM crops is a significant determinant of the level of accuracy of their knowledge about GM crops.

As shown in Table 1, majority (55.5%) of respondents whose accounts of GM crops were found to be wholly factual did not source their information from the mass media. This means that those who sourced their information on GM crops from colleagues, extension officers and input dealers are more likely to have accurate information on GM crops than those who sourced their information from the mass media. Similarly, about 58% of respondents whose accounts of GM crops were partly factual sourced their information on GM crops from other sources other than the mass media.

As shown in Table 1, overwhelming majority (73.3%) of the respondents who provided mythical accounts of GM crops sourced their information from the mass media. The mass media therefore provided a medium for churning out all kinds of misinformation about GM crops. Some of the information was not only untrue but boarder on myths and fairy-tales which are influencing farmers' knowledge and view on GM crops and agrobiotechnology in general.

The apparent lack of scientific information about GMOs in the public domain is worrying, considering the fact that the mass media is an important driver of GMO standards as found in Vigani and Olper (2013). Zakaria et al. (2020) also found source of information on GM crop as a significant driver of smallholder farmers' adoption decision. The mass media have been an important source of information on GMOs and as such the main driver of public opinion about the safety or otherwise of GM products. Raman (2017) found the use of mass media as channel through which dystopian and apocalyptic narratives about GM food and Bt cotton are churned out by social movement campaigners against GMOs using strong visuals to enforce public disapproval of GM products.

Also, within the context of the debate over GM foods and crops, it is difficult to know where scientific evidence ends and where dogmatism and speculations begin because the mass media is inundated with all kinds of information and misinformation about GMOs. Zakaria (2020) upon excessive review of literature on the debate concluded that public interest and safety will be better served and safeguarded if GMOs proponents and opponents reached consensus on standardization regarding tolerable level of harm and acceptable safety limit in interpreting impact assessment results of GMOs on health and environment.

Farmers' self-assessment about their knowledge of GM crops

In examining farmers' self-assessment about their own knowledge of GM crops, respondents were asked: 'how well informed they were about GM crops'. Their responses were categorised into 'very well informed' if respondent thought he/she had much information on GM crop, 'somewhat informed' for respondents who thought they had some level of information and knowledge on GM crops and 'not informed at all' if respondent thought he/she lacks information on GM crops. Results of analysis of responses to this question are as shown in Figure 3. Only 8% of the respondents thought that they were very well informed about GM crops, while close to a quarter (18%) thought that they were just not well informed about GM crops. However, majority (74%) indicated that they were somewhat informed about GM crops.

Farmers' source of information on GM crops was expected to influence their self-assessed knowledge on GM crop. Respondents' sources of information on GM crops included mass media (mostly radio and TV), from their colleagues, extension officers and agro-input dealers. A cross tabulation of source of information on GM crops and respondents' self-assessed knowledge of GM crops shown in Table 2 demonstrates significant relationship between respondents' source of information

Table 1. Source of information and accuracy of knowledge on GM crops.

Source of information	Accuracy of knowledge about GMOs						Total
	Mythical	Mixed up	Wholly factual	Partly factual	Wholly Fictitious	Misconstrue	
Mass Media	22 (73.3)	26 (30.6)	28 (44.4)	23 (41.8)	41 (43.2)	16 (50.0)	156 (43.3)
Others	8 (26.7)	59 (69.4)	35 (55.5)	32 (58.1)	54 (56.8)	16 (50.0)	204 (56.7)
Total	30 (100.0)	85 (100.0)	63 (100.0)	55 (100.0)	95 (100.0)	32 (100.0)	360 (100.0)

$\chi^2 = 17.282$; df = 5; P>| χ^2| = 0.004; Note that figures in brackets denotes column %.
Source: Analysis of Field Survey Data (2016).

on GM crops and their self-assessed knowledge about GM crops. With a Chi-square value of 29.565 (χ^2 = 29.565; df = 2; P>| χ^2| = 0.004), the analysis established significant relationship at less than 1% level of significance between source of information and respondents' self-assessed knowledge of GM crops. Respondents who sourced their information on GM crops from mass media were found more likely to rank their knowledge about GM crops as 'very well informed' compared to those who sourced their information from other sources such as colleague farmers, extension officers and agro-input dealers.

Also as shown in the Table 2 about three quarters (78.2%) of the respondents who sourced their information from the mass media claimed to be 'somewhat informed' about GM crops while only 7.7 and 26%, respectively of those who sourced their information on GM crops from mass media and others ranked themselves as 'not informed at all.

Effectively, respondents who sourced their information on GM crops from the mass media are very confident of their knowledge on GM crops compared to those who sourced their information on GM crops from other sources. This demonstrates the trust and confidence smallholder farmers have on information coming from radio and television. This confirmed the claim by Vigani and Olper (2013) that the mass media drive and shape public views and perceptions towards GM crops. This is worrying considering the fact that this study confirmed that respondents who sourced their information about GM crops from the mass media are more likely to have inaccurate knowledge compared with those who sourced such information from their colleagues, extension officers or input dealers.

Farmers' opinion on the benefits and disadvantages of GM crops

Three main issues ran through the narratives of respondents concerning their views on the possible benefits of GM crops. The three main issues are (1) 'improved food security', (2) 'increased farm profitability' and (3) 'reduced labour intensity'. These views about the possible benefits of GM crops were found to be widely shared by the 360 respondents interviewed. Most of them mentioned all the three issues; others mentioned only two or one.

Analysis of individual responses to a question 'what do you think are the possible benefits of GM crops?' revealed that the three main issues characterising respondents' opinion on the benefits of GM crops are widely held among most of the respondents surveyed. Most (80.2%) of the respondents were of the opinion that the cultivation of GM crops will help improve food security situation through increase in production and productivity. They were of the view that GM crops are high yielding because of their improved traits against crop production problems such as weed and insects infestations. They indicated that the cultivation of such crops will lead to increase in food production which will go a long way to improve on the food security situation.

The argument of whether GM crops, for that matter agrobiotechnology, can contribute to improving food security and ending global hunger abounds in literature. Fukuda-Parr and Orr (2012) asserted that, the question 'can GM crops help improve food security, especially in Africa?' can be adequately addressed by examining whether the new varieties are beneficial to small scale farmers and whether it actually addresses the food security concerns of developing countries? Micro-impact studies and short-term analysis of farm productivity among smallholder farmers who have adopted the cultivation of GM crops have demonstrated positive impacts on household income and food security (Brookes, 2017; ISAAA, 2019; Paarlberg, 2010).

Majority (57.7%) of the respondents also shared the view that GM crops cultivation has the potential of increasing farm profitability through increased productivity and reduced cost of production. They were of the opinion that the high yielding nature of GM crops makes it possible for them to benefit economically from its cultivation. As was observed by a respondent:

'*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 harvest to feed ourselves and our*

Table 2. Source of information and self-assessed knowledge on GM crops

How well inform are you about GM crops		Main source of information on GM Crops		Total
		Mass Media	Others	
Very well informed	Count	22	7	29
	% column	14.1	3.4	8.1
Somewhat informed	Count	122	144	266
	% column	78.2	70.6	73.9
Not informed	Count	12	53	65
	% column	7.7	26.0	18.1
Total	Count	156	204	360
	% column	100.0	100.0	100.0

$\chi^2 = 29.565$; df = 2; $P>|\chi^2| = 0.004$
Source: Analysis of Field Survey Data (2016).

households…' (Personal interview, Northern region, Ghana, September, 2016).

There is a large body of peer-reviewed literature indicating higher economic returns on GM crops to small scale farmers (ISAAA, 2019; Brookes, 2017; Raman, 2017; Paarlberg, 2010). Therefore, the view among respondents that cultivating GM crops have the potential of increasing farm productivity and profitability is supported by empirical data.

However, just a little below half (48.1%) of the respondents included reduce labour intensive nature of crop production in their list of potential benefits of GM crops. They explained that with the cultivation of Roundup Ready (RR) traits of GM crops, the labour intensive nature of weed control will be much reduced. They observed that weed control is one of the areas of labour intensive operations in crop production. And as such adopting the cultivation of RR GM crops will bring relief to them regarding their current difficulties in controlling weeds.

With regard to potential disadvantage which might be associated with the introduction of GM crops, respondents identified four main concerns or fears about cultivation of GM crops. These issues are (1) environmental and health risks, (2) high cost of GM seeds, (3) destruction of local and indigenous varieties of crops, and (4) unreliable seed supply and viability. The respondents got all these information about the possible negative effects of GM crops mostly from discussions on radio and television. A respondent made this observation:

''*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).

Participants at the various focus group discussions reiterated some of the worrying environmental and health risk warning they had heard on radio and other mass media regarding the cultivation and consumption of GM crops. They enumerated possible environmental effects of GM crops ranging from destruction of biodiversity to cross pollination of GM crop varieties with their wild relatives. They also raised health concerns such as possible food poisoning and toxicity caused by roundup resistant GM crop varieties, allergic reactions and carcinogenic effects among others.

Most (80.2%) of the respondents interviewed mentioned possible environmental and health risks as one of the main disadvantages of cultivating GM crops. They were of the view that many consumers would not like to consume GM foods because of the possible health risk that have been trumpeted to be associated with GM products. As a result, most of them expressed reservations about adopting GM crop cultivation.

Many anti-GM activists have been stressing the fact that GM foods might have negative impact on the environment and human health (Qaim, 2015; Lu, 2008; Smith, 2007). Anti-GM foods advocates have long maintained that, since there is no consensus among independent scientific studies on the safety of GM crops for animals or humans, its consumption should not be rushed into the food chain (Domingo, 2007; Vain, 2007; Brown, 2003). It is some of the anti-GM information being churned out in the media landscape that is shaping the views of respondents interviewed in this study.

As shown in Table 3, possible high cost of GM seeds was also identified by 71.1% of the respondents as one of the disadvantages of GM crops cultivation. Respondents were of the view that GM seeds might be too costly for smallholder farmers to buy. They fear that the high capital investment in producing GM crops

Table 3. Respondents' knowledge of the possible benefits/disadvantage of GM crops.

Knowledge of benefits/disadvantages of GM crop		Frequency*	Percentage
Benefits of GM crops	Improved food security	289	80.2
	Increase farm profitability	208	57.7
	Reduce labour intensive	173	48.1
Disadvantages of GM crops	Environmental and health risks	209	58.1
	High cost of GM seeds	256	71.1
	Destruction of local/endogenous varieties	189	52.2
	Unreliable seeds (supply & credibility)	215	59.7

*Multiple responses.
Source: Analysis of Field Survey Data (2016).

coupled with the patent regimes accompanying GM seeds production and distribution will make GM seeds very expensive to cultivate. GM seeds production and distribution are often guided by Intellectual Property Right regimes which grant biotech companies patents over GM seeds (Specter, 2014; Katiraee, 2014; Bhuiya, 2012; Shiva, 2006). This arrangement prevents farmers from generating their own seeds when they cultivate GM crops. Farmers in the study area are used to selecting, preserving and using seeds they have control over. They often select seeds from their harvest and store for the next planting season and sometimes share seeds among themselves as indigenous farmers.

This gives them absolute control over their seeds and indigenous crop varieties.

Possible destruction of local and indigenous varieties was also mentioned by 52.2% of the respondents as one of the disadvantages farmers in Ghana will be faced with if commercialization of GM crops is allowed (Table 3). Their explanation was that GM crops might replace their indigenous crop varieties, and this will compel them to continuously depend on biotech companies for their seeds supply.

Anti-GM crops activists often argue that the patents regulatory regime accompanying the development of GM seeds have the tendency of shifting local control of seeds to biotechnology companies. As observed by Katiraee (2014), the common criticism of genetically modified foods is that their seeds are patented to developers who are mostly profit motivated multinational corporations. There is the fear that the seeds local farmers have been using over the years will give way to the use of genetically modified seeds.

Another possible disadvantage of GM crops expressed by 59.7% of the respondents is the fear that the supply of GM seeds from biotech companies might not be reliable and the viability of the seeds might also not be guaranteed. Respondents argued that agricultural input supply, especially certified seeds, are not properly managed and regulated. They fear that GM seeds supply might not be timely and readily available on the open market. An elderly respondent observed:

'*I stopped buying certified seeds because they are not reliable, anyone can bag any seed and label it as certified seed and you will buy it and later realise that the seeds are not good. One may even ask who is watching over those selling the certified seeds to us?*'' (Key informant interview, Northern region, Ghana, November, 2016).

Despite the significant improvement in seed regulation and marketing, farmers surveyed still expressed reservations about the reliability of certified seed supply and marketing.

However, due to considerable government efforts through seed regulatory enactments (Plant and Fertilizer Act 803, Prevention and Control of Pests and Diseases of Plants Act of 1965, Act 307 and Seed Inspection and Certification Decree, NRCD 100 of 1972) and government seed policy, the formal seed system in Ghana has undergone significant improvement with increasing private investment in seed production (IFPRI, 2013).

Conclusion

The knowledge and understanding of smallholder farmers in Northern Ghana about GM crops can be described as generally patchy and vague with some having factual, partly factual, fictitious, mythical and misconstrued knowledge and understanding about GM crops. However, their source of information on GM crops was found to be a significant determinant of the accuracy of their knowledge and understanding about GM crops. Smallholder farmers who heard of GM crops from extension officers, agro-input dealers, and friends/ relatives were found to be more likely to have accurate or partly accurate knowledge and understanding about GM crops compared with those who got to know of GM crops from the mass media, particularly radio and television.

Recommendations

Based on the major findings of this study, the following

recommendations are made:

(1) National Biosafety Authority (NBA) in conjunction with the Ministry of Food and Agriculture (MoFA) should intensify their public education on GM crops and particularly engage Members of Farmer Based Organizations (FBOs) in their education drive.
(2) MOFA, NBA and other relevant stakeholders should institute training programme to build the capacity of members of FBOs to enable them contribute meaningfully to Ghana's biotechnology policy and implementation strategies.
(3) NBA should strengthen its public education, sensitisation and advocacy on agro biotechnology and GM crops through the media, particularly radio and television.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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