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How do scientists promoting genetically modified seeds in Africa build trust? The experience of Ghanaian Farmers

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Abstract

The use of genetically modified organism (GMO) technology in food systems continues to generate considerable controversy globally. Similar controversies have accompanied the introduction of genetically modified (GM) cowpea, which its developers say has inherent resistance to *Maruca vitrata* pest attacks, in Ghana. In light of the controversy surrounding the technology and the heavy international donor involvement in the development of the seeds, this qualitative study sought to understand how the scientists who introduced GMOs in Ghana gained the trust of farmers. We found that specific characteristics of the farmers, specific characteristics of the scientists, and the actions that scientists took in their engagement with farmers, were the three key determinants that encouraged trust. The Ghanaian cowpea farmers had inherent characteristics such as risk tolerance and high confidence in intermediaries. These made them predisposed to trusting the scientists. The scientists were effective messengers of the technology, worked with a reputable institution, and showed practically how the technology works. We recommend future GMO dissemination initiatives in Africa be public sector led, in partnership with private sector. We also observe that farmers are less receptive to the linear model of technology transfer and encourage African scientists to use interactive networking approaches if they want to build more trust with farmers on adoption of technologies.

Keywords

GMOs, Farmers, Scientists, Science Communication, Trust, Africa, Ghana

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The use of genetically modified organism (GMO) technology in food systems continues to generate considerable controversy globally. Similar controversies have accompanied the introduction of genetically modified (GM) cowpea, which its developers say has inherent resistance to Maruca vitrata pest attacks, in Ghana. In light of the controversy surrounding the technology and the heavy international donor involvement in the development of the seeds, this qualitative study sought to understand how the scientists who introduced GMOs in Ghana gained the trust of farmers. We found that specific characteristics of the farmers, specific characteristics of the scientists, and the actions that scientists took in their engagement with farmers, were the three key determinants that encouraged trust. The Ghanaian cowpea farmers had inherent characteristics such as risk tolerance and high confidence in intermediaries. These made them predisposed to trusting the scientists. The scientists were effective messengers of the technology, worked with a reputable institution, and showed practically how the technology works. We recommend future GMO dissemination initiatives in Africa be public sector led, in partnership with private sector. We also observe that farmers are less receptive to the linear model of technology transfer and encourage African scientists to use interactive networking approaches if they want to build more trust with farmers on adoption of technologies.

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Introduction

The use of genetically modified organism (GMO) technology in food systems continues to generate considerable controversy globally (Kikulwe et al., 2011; Raman, 2017). While some researchers claim that GMOs have benefited farmers, consumers and the environment, others are critical of the technology (Brookes, 2022a; Ezezika et al., 2012; Raman, 2017; The Breakthrough Institute, 2023). According to Brookes (2022a), between 1996 and 2020, genetically modified (GM) crop technology increased food, feed, and fiber production by nearly one billion tons and reduced the pressure to bring new land under agricultural production. The technology also helped farmers around the globe earn $261.3 billion in additional net income, and reduced the environmental footprint associated with crop protection practices by more than 17% (Brookes, 2022b). However, backlash about patenting, increased dependency on proprietary seeds, tampering with nature and alteration of the fundamental genetic makeup of organisms, possible impact on biodiversity, and the potential unintended spread of GM traits to wild populations, continue to hinder the technology's adoption (Jones et al., 2017; Karalis et al., 2020).

The debates surrounding safety, ethics, sustainability, and sovereignty in agricultural production have encouraged some nations in Europe to enact precautionary regulatory frameworks for GMOs, while those in the Americas follow less stringent procedures (Bickell, 2019). African governments are struggling to lay out clear policy directions on GMOs because even though the USA is pressing them to adopt, European governments are pressuring them to reject (Falkner & Gupta, 2009; Muzhinji & Ntuli, 2021). As a result, GM crops are commercially available in only seven of Africa's 54 countries (The Breakthrough Institute, 2023). Outside of South Africa, GM crops are new to majority of farmers across the African continent (Brookes, 2022a). The critical factor that helped ensure the widespread adoption of the first GM crop (Bt maize) in South Africa was the trust farmers had in the agricultural innovation delivery system and the continuous success of the technology will likely depend on deliberate efforts by sector actors to maintain the trust (Ezezika et al., 2012).

Trust is the willingness of individual A to relinquish control and vulnerably accept the directions of individual B, regardless of the potential risks that await individual A, based on individual A's confidence in individual B (Adjekum et al., 2017, Schoorman et al., 2007). When a trustor trusts a trustee, the belief exists that the trustee will not use their better knowledge of a situation for their self-interest but instead prioritize the interest of all parties equally (Buck & Alwang, 2011). As Licht and Brülde (2021) observed, trust has great value, can encourage the preservation of common resources and help ensure the good of societies. Trust is a crucially important element when dealing with new technologies that have both present and future consequences (Adjekum et al., 2017). Trust in food systems is built on the assurances provided by both individual food product producers and the different actors within the food system, and plays a pivotal role in shaping relationships (Meyer et al., 2017; Wu et al., 2021). Without trust,

markets would struggle to operate efficiently and effectively because trust serves as the foundation on which transactions are conducted (Benson et al., 2020).

After interviewing stakeholders involved in public–private sector GMO initiatives across eight countries in sub-Saharan Africa, Ezezika and Oh (2012) described trust in the context of agricultural biotechnology as "an expectation held by an individual that the performance and behavior of another will be supported by tangible results; facilitated by competency and transparency; grounded in a shared vision; and guided by integrity and an interest for the common good" (p. 1). Adjekum et. al. (2017) proposed a framework for building trust in the diffusion of precision medicine technology, identifying technological innovation, ethical and sociocultural values, and institutional practices and governance measures, as three key facilitators of trust. Newman and Briggeman (2016) observed that credibility, reliability, intimacy, and self-orientation (showing one has the customer at heart) are four crucial elements that encourage farmer trust. Benson et al. (2020) identified trustworthiness, competence, benevolence, integrity, openness, and honesty as some of the most important components of trust. Actors in the food safety industry identified transparency, adherence to protocols and procedures, proactive behavior, collaboration with stakeholders, and prioritizing consumers as the most effective strategies for building consumer trust (Wilson et al., 2017). From the above mentioned, we concluded the litany of factors that facilitate trust in agriculture can be grouped into characteristics technology promoters display, characteristics of consumers of these technologies including farmers, and the actions technology developers undertake.

GMOs in Ghana

In Ghana, GM cowpea or black-eyed peas - the country's first-ever GM crop, was first introduced to farmers in the northern part of the nation in the mid 2010s by scientists in a pilot trial which the National Biosafety Authority mandated, before approving it for environmental release in 2022 (Ampadu-Ameyaw et al., 2021; Gakpo & Baffour-Awuah, 2024). Environmental release approval allows for widespread use of the GM crop as food and feed by the general public (Gakpo et al., 2025; National Biosafety Authority, 2022). From 2015 to 2022, farmers grew GM cowpea as part of multilocation trials conducted by the technology developers to collect data on its performance to apply for environmental release approval (Alliance for Science, 2017; National Biosafety Authority, 2022), and some farmers consumed portions of the harvests. The GM cowpea was the result of collaborative works between Australian, U.S., and Ghanaian scientists, with funding from USAID, Bayer, and other international institutions through the Kenyan-based African Agricultural Technology Foundation (African Agricultural Technology Foundation, n.d.).

Cowpea (*Vigna unguiculata* [L.] Walp) is a drought-tolerant crop used as food for humans and feed for animals and well-adapted to a diverse range of climate and soil types (Gondwe et al., 2019; Karikari et al., 2023). It is a vital crop for food and nutritional security in West Africa, where more than 200 million people consume it as one of their major sources of

protein (Donald Danforth Plant Sciences Center, n.d.). Cowpea is described as the poor man's meat because it is a significant source of protein for rural people who have limited access to protein from animal sources (Gondwe et al., 2019; Haruna et al., 2018). Cowpea is also a rich source of calcium, iron, and vitamins and plays a major role in boosting the protein-energy status of children under five years of age in Africa (Haruna et. al., 2018; Okonya & Maass, 2014). According to Martey et. al. (2021), widespread adoption of improved climate-smart cowpea varieties could enhance food and nutrition security in Ghana.

Cowpea farmers in Ghana would usually spray their fields with pesticides up to eight times in the 12-week life cycle of the crop because of widespread infestation by the maruca pod borer (*Maruca vitrata*) pest, thereby polluting the atmosphere, poisoning farm workers, and reducing farmer profits (African Agricultural Technology Foundation, 2022). But the GM cowpea known as the pod borer resistant (PBR) cowpea or Bt cowpea, which was developed through the introduction of a gene from a naturally occurring bacteria, *Bacillus thuringiensis (Bt)*, has inherent immunity to the pest and requires only two sprayings (Kumar et al., 2021).

Although some farmers have been exposed to GMOs, previous studies have reported they have limited information about the technology. A study assessing farmers' understanding of GMOs among members of Farmer-Based Organizations in northern Ghana revealed smallholder farmers in the region have a patchy and vague understanding of GM crops (Zakaria et al., 2022). A survey by Ampadu–Ameyaw et al. (2021) on public awareness, participation, and attitude toward the national biosafety framework and genetically modified organisms in Ghana revealed farmers had the lowest level of awareness, noting this was problematic because they were the main target of GMOs.

Purpose of Study

In light of the controversy surrounding the technology and the heavy international donor involvement in the development of the seeds, we sought to understand Ghanaian farmers' perspectives on engagement with the scientists who introduced them to their nation's first GMO. We aimed to explore how scientists earned the trust of farmers, leading them to agree to cultivate GM cowpea seeds on their farms. Guided by the work of Ezezika and Oh (2012) and Ezezika et al. (2012), this study investigated the characteristics and actions that helped build trust between farmers and scientists in Ghana. Minimal research existed on the best practices for building trust and enhancing trusted relationships in the agricultural sector despite the admission by all stakeholders that trust is integral to maintaining successful relationships, especially in food systems (Newman & Briggeman, 2016).

Theoretical Framework

The Risk Perception Model describes an individual's perception of risk as a combination of two factors: hazard—which is determined by the magnitude and probability of mortality or

morbidity—and outrage, the emotional or perceptual response to risk, including fear and anxiety (American Industrial Hygiene Association, 1993; Davis et al., 2003). Risk is the chance of encountering harm or negative consequences due to a particular decision or action (Hardaker et al., 2015). This decision or action may also bring potential benefits, which can either outweigh or be outweighed by the associated risks (Jianjung, 2015). Various factors impact people's perception of risks with psychological factors such as emotions and biases playing a bigger role in how people evaluate risks than objective assessment of data (Slovic, 1987).

Also, cultural values, shared beliefs, past experiences, social norms, group identity, level of control, and media coverage of technologies, are some of the other factors that shape how risks are perceived (Gorman, 2013; Slovic, 1987). People may engage in risky behaviors when they find themselves in environments where such is encouraged (Campbell Institute, n.d.). People are also usually careful about going against the judgement of the majority in their communities and so having peers who engage in risky behaviors can encourage one to do the same, and vice versa (Campbell Institute, n.d.). Perception of risks and benefits, knowledge and trust, as well as personal values are key factors that influence consumers' attitudes on acceptance or opposition to technologies (Lucht, 2015). As consumers' trust in a technology increases, the perception of risks decrease, often reaching a minimal level with time (Ji et al., 2019). Public acceptance of GM technology is influenced by perceived risks; the higher the perceived risks, the lower the acceptance rate and the lower the perceived risks, the higher the acceptance of the technology (Ali et al., 2020; Lucht, 2015; Lusk et al., 2018; Rodríguez Entrena & Ordóñez, 2013). Public acceptance of GM technology is also shaped by the level of trust in technology developers and regulatory institutions (Lusk et al., 2018). This model was appropriate for our study because it helped us understand how the risk perception farmers hold about GMOs influenced their trust in the scientists who introduced them to the technology.

Methodology

This study received approval from North Carolina State University's Institutional Review Board with protocol number 26147. This was a qualitative study that used face-to-face, semi-structured interviews to gather data. The use of semi-structured interviews to gather data allowed for follow-up questions and ensured that the conversation unfolded freely but was guided (Creswell, 2007; Oakley, 1998). We contacted Ghana's Ministry of Food and Agriculture and sought the contact information of leaders of farmer groups in the northern part of the country. We sought contacts of farmers in the Northern Region, North-East Region, Savanna Region, Upper East, and Upper West Region. A list of 18 key informants was supplied to us. We reached out to these leaders and asked them to help identify members who had grown GM cowpeas. Farmers were selected to be interviewed for the study if they met the following criteria: farmed in the northern regions of Ghana, engaged with technology developers (scientists) prior to the use of GM

cowpea seeds, and had grown GM cowpea seeds in the last decade. Thirty such farmers were identified out of which we interviewed 22 face-to-face. The other eight were unavailable during the time we visited the regions. The interviews were audio recorded, with prior consent of the farmers, and transcribed for analysis. As Oakley (1998) observed, in order to have the interview data captured more effectively, interviews should be recorded because handwritten notes alone may miss some of the key points.

Trustworthiness is crucial to ensure confidence in the data, and the four main characteristics that define trustworthiness in qualitative data are truth value, applicability, consistency, and neutrality (Guba, 1981; Krefting, 1991). We ensured truth value and consistency in our data gathering and analysis. Truth value asks whether the researcher has established confidence in the truth of the findings and it is usually sought from the discovery of experiences of the informants (Krefting, 1991). In this study, we interviewed farmers for their views on their relationships with the scientists who introduced them to GMOs. They shared with us the truth from their viewpoints and we reported exactly that in the results section. In qualitative research, consistency is defined in terms of dependability (Krefting, 1991). Guba (1981) said that dependability implies variability that can be ascribed to identified sources. Variability, meanwhile, stems from the fact that qualitative research looks at the range of experiences rather than the average experience. In this study, we sought a range of perspectives from the farmers we interviewed. We interviewed a mix of male and female farmers, as well as young and old farmers. We also interviewed farmers who grew GM cowpeas as part of trials eight years ago, some who grew the seeds as recently as three years ago, and some in between these times. As Creswell & Poth (2018) cautioned, because qualitative researchers are usually in the field, they may lose track of the need to present multiple perspectives, side with some interviewees on various issues, and only disclose positive results. We avoided this by shying away from leading questions. In addition, the two researchers did not agree on all issues surrounding the use of GMOs and thus could balance each other's tendencies to take sides in analyzing the results.

The recorded audio interviews were all transcribed. We did open coding of the transcripts to identify units as Creswell and Poth (2018) encouraged. We subsequently grouped the units together to derive themes. Of the themes, patterns were developed. And from patterns, categories were developed (Creswell & Poth 2018; Saldaña, 2021). We applied Ezezika and Oh (2012), Newman and Briggeman (2016), Benson et al. (2020), Wilson et al. (2017), and Adjekum et al. (2017) frameworks of trust to analyze how the scientists who introduced Ghanaian farmers to GMOs gained their trust.

Findings

We found that characteristics of the farmers, characteristics of the scientists, and the actions that scientists took in their engagement with farmers were the three key determinants that influenced trust in GMO scientists. This trust then facilitated the use of GM cowpea seeds by the farmers.

Characteristics of Farmers that Helped Build Trust

Vulnerability and Risk Tolerance

The farmers described themselves as vulnerable smallholder producers with low economic status, and inadequate finances to purchase pesticides to deal with pest infestation in their fields. This likely made them risk-tolerant, displaying willingness to take chances and experiment with the new GM seeds. Despite uncertainties surrounding the new technology, they were ready to explore its potential benefits because they perceived limited options existed for controlling the pests. Farmers voiced a sense of helplessness in the face of severe pest infestations on their cowpea fields by the *Maruca vitrata*. Farmer L said: "Pest infestation is very high here. Very high. So, if I can have cowpea that I will spray twice and that is it, why not go for that?" The farmers urgently needed solutions and that likely encouraged them to take risks and trust the scientists' assurances that GM cowpeas would resist the pests. Farmer C stated: "We were not convinced as such. I, in particular, was not convinced as such. But we gathered courage and followed them to do it."

High Level of Confidence in Intermediaries

The farmers appeared to have a high level of confidence in the intermediaries who were collaborating with the scientists, such as extension agents, veteran farmers, and respected community members. This confidence in the intermediaries played a crucial role in their decision to trust the scientists and try the GM seeds. The farmers relied on the expertise and guidance of these intermediaries, valuing their opinions and recommendations. Farmer B mentioned:

> We have the trust in them [the scientists], especially the intermediate between us. The officer from Tamale, Mr. A. R., the extension agent. He is a trusted one. If we trust him, then we can trust those scientists who came to educate us.

The prior strong relationships between the farmers and these intermediaries were instrumental in bridging the gap between the farmers and the scientific community. When farmer Q was asked what made him decide to plant the GM seeds, he said:

> It was one of my friends, Mr. P. [a veteran farmer in the community]. He informed me about the GM cowpea. So when I realized that, I saw it is a nice variety. Mr. P. is just my best friend as we work together. Any problem I have, I will consult him for him to explain to me so I get the understanding. Actually, I don't hide anything from him.

Encouraged by Peer Validation

In addition, the farmers seemed to highly value peer validation in their decision-making processes, and that encouraged them to trust the scientists. Some farmers planted the GM seeds based on the recommendation of their peers. “Some people started earlier with the scientists. That is why I was also involved. So, I know everything will be okay by God’s grace. They believed in the GMO which is why they brought it. So, I trusted them,” recalled Farmer L. When colleagues of the farmers visited their GM cowpea fields and praised how the fields looked, they were motivated to continue planting the novel seeds. Farmer C said: “When people came to my farm, I had just planted GM cowpea. So, I took some of the women to come look at it. And they liked it.” This peer validation served as a form of approval, reinforcing their belief in the effectiveness of the GM cowpea variety. The positive comments from their peers about GMOs boosted their confidence in the new technology and provided them with a sense of community support. The farmers viewed their colleagues' approvals as a reliable indicator of the GM cowpea's potential benefits, leading them to feel more confident in their decision to trust the scientists and adopt the new variety.

Apprehension and Skepticism

Prior to agreeing to plant the GM cowpea seeds, some farmers were skeptical and apprehensive. Farmer D said:

> You know that culturally and socially, we are different people. And politically, we are different. When some of us raised the questions about the GMOs, some people thought it was political. But we said no. It was our health that we were concerned about.

And farmer I, stated: “I was questioning. GMO. Genetically modified something. Won't people be afraid to even consume it? The repercussions.” Farmer O added: “We were saying that the way these insects are severe here, there is a probability it won’t work.” For these farmers, the decision to try GMOs was fraught with doubt and caution. The farmers, however, overcame their apprehension, likely due to their vulnerability, risk tolerance, confidence they had in the intermediaries and peer influence.

Characteristics of Scientists that Helped Build Trust

Effective Messengers

The farmers said that the scientists were effective messengers of the GMO technology. They framed GMOs as a technology that could directly benefit farmers and contribute to the greater public good. The scientists appealed to the farmers’ self-interests and desires to improve their livelihoods in the messages they delivered to them. They assured the farmers that GM cowpea is substantially equivalent to conventional cowpea seeds except for the introduction of the gene responsible for pest resistance. “He convinced us by telling us that it's biological. But the treatment given to the plant is what makes it look synthetic. But it is not synthetic. It is as good as any beans that we know,” noted farmer I. Farmer S also observed: “The scientists said

with what they have done so far in gardens and confined places, GMOs are equally as good as the local ones that we consume." Others were convinced by the message that the seeds would help them improve yields. Farmer C said: "They told us how it yields better." The farmers explained that they accepted instructions from and followed the lead of the scientists because they looked and sounded as experts on the technology. Farmer J retorted: "They were really like officials who have been into cowpea farming for some time. They looked like experienced cowpea farmers. So, we listened to whatever they had to say." Farmer J explained: "I have not engaged them before. But looking at their expertise, they wouldn't deceive me."

Farmers often found themselves in a precarious position, balancing both vulnerability and a willingness to take risks in the face of uncertainty. The reassuring communication from the scientists played a crucial role in bridging this gap. Communicating the benefits of the technology and addressing farmers questions helped shift farmers from a state of hesitation to proactive decision making. This emphasizes the importance of effective communication and trust-building in encouraging the adoption of new agricultural technologies.

Work with a Reputable Institution

The involvement of scientists working with the Savannah Agricultural Research Institute (SARI) - a reputable scientific institution in Ghana - in the technology dissemination process, played a significant role in helping build trust and encouraged farmers to plant the GM cowpea seeds. The reputation of SARI as a respected agricultural research institute lent credibility to the scientists. For many years, SARI delivered to farmers improved conventionally bred seeds and the farmers know the institution well. This good reputation instilled confidence in the farmers, reassuring them that the GM cowpea seeds were backed by sound scientific research and expertise. SARI is also famous in some of the communities because officials of the institution are occasionally featured in media interviews. Farmer H stated: "These people, we have been hearing about them on TV and radio. So that one convinced me that, now that they said they are from SARI, let me also try it and see." The association with SARI helped bridge the gap between the scientific community and the farmers, encouraging a sense of trust. Although some of the farmers were initially apprehensive and skeptical about GMOs, they took risks on the technology because they were dealing with scientists from an institution of great repute.

Actions Scientists Took that Helped Build Trust

Built Collaborative Relationships

The farmers observed that the scientists encouraged a culture of mutual collaboration. The farmers said the scientists actively engaged them in the decision making processes regarding planned sensitization activities on the GMO cowpea. They took farmers' perspectives into consideration and involved them in the planning of various activities. This collaborative approach created a sense that the GM solution was relevant and responsive to their agricultural challenges, and helped build trust. Farmer B explained: "Normally, they also listen to what we

also have. If it is beneficial, then they will take it." The scientists also paid regular visits to the farmers to assess the progress of their GM cowpea fields. Farmer L said:

> They were with us all the time. They guided us on how to plant. Then after the germination, they came again. They inspected it. From any level it reaches, they will come. Then they came and guided us on how to harvest.

The frequent engagements helped the scientists build rapport with the farmers and establish strong relationships.

Practical Demonstration

The scientists practically demonstrated to the farmers how the technology works by setting up demonstration plots. These plots served as real-life examples showing the potential benefits of the GM cowpea seeds. Farmer D in response to a question about what motivated him to plant the GMOs said:

> Actually, they started field visits. Asking farmers to come to the fields to see. I was part of the field visit. So, when we came and saw it, we actually saw the difference. So, that is the time that we were encouraged.

Providing tangible evidence of the technology's effectiveness helped the farmers visualize the potential impacts of accepting GMOs. Farmer C stated: "It [demo plots] was good for us. Simply because when you compared to farmer varieties, this [GM cowpea] grew earlier. And the yield was more than the farmers' varieties." The demonstration plots showed that the technology did what they said it would do and that likely facilitated trust. Vulnerable farmers only needed clear cut assurances that alternative technologies work, and then they may be inclined to explore that solution. The demonstration fields provided them exactly that.

Discussion

We found that farmers' vulnerability and risk tolerance, their confidence in intermediaries, and their receptiveness of peer validation were inherent characteristics that helped build trust with the scientists. Also, effective messaging by the scientists, working with a reputable institution, building of collaborative relationships and practical demonstration of the technology, helped build trust. Public acceptance of GM technology is shaped by perceived risks: greater perceived risks lead to lower acceptance, while lower perceived risks increase acceptance of the technology (Ali et al., 2020; Lucht, 2015; Lusk et al., 2018; Rodríguez Entrena & Ordóñez, 2013). The farmers' assumptions that a lower risk existed in trying the GM seeds likely encouraged them to plant the seeds despite the controversies surrounding the new technology. A farmer may be risk-tolerant, risk-averse, or risk-neutral, and their risk preferences influence the decisions they make on whether to adopt new agricultural innovations (HarvestChoice, 2010; Musyoki, 2022). The farmers who grew the GM cowpea appeared to be

risk-tolerant, and to their minds, the perceived benefits of GM cowpea, including reduced pesticide use, outweighed their perceived risks. In addition, people are more likely to engage in risky behavior in environments that promote it but tend to exercise greater caution in settings where risk-taking is discouraged (Campbell Institute, n.d.). People seek to avoid social isolation, often by joining a social group and adopting its viewpoints (Lamm et al., 2020). More farmers were likely encouraged to plant the GM seeds because their colleagues were planting the seeds.

The decision by the scientists to work with intermediaries in whom the farmers had prior confidence, including extension agents and veteran farmers in the communities, also helped encourage trust. Trust can be cultivated through a transference process, leveraging a mediator or intermediary to facilitate the establishment of trust between two parties, with the intermediary serving as a bridge, helping to build rapport, clarifying communication, and managing expectations (Newman & Briggeman, 2016). The extension agents who acted as intermediaries had been working with the farmers for many years, introducing them to new farming techniques and conventional improved seeds. The trust farmers had in these intermediaries were likely transferred to the scientists. The scientists also capitalized on the reputation that the Ghana government-funded Savanna Agricultural Research Institute (SARI) has among farming communities to get the farmers to trust them. Since its establishment in 1994, SARI has equipped farmers with various technologies, including enhanced seed varieties, to boost their food and fiber crop production through a sustainable system that preserves and enhances soil fertility (Savanna Agricultural Research Institute, n.d.). SARI has used conventional breeding practices to develop improved seeds for farmers, and because the GMO scientists work with SARI, they did not shy away from drawing the farmers' attention to that relationship. Local institutions usually have social capital built over several years of interactions that positions them to lead behavioral change efforts (Lai Nguyen et al., 2020). When farmers are introduced to technological information, they do not create meaning of science in isolated ways but tend to process and understand the science in the cultural, social, economic, and political context of their daily lives and the communities in which they resided (Hicks, 2017; Rogers, 2003; Secko et al., 2013). This highlights the importance of local institutional credibility and collaboration in promoting the adoption of new agricultural technologies, as such institutions have strong understanding of the social and cultural contexts in which the farmers operate.

Effective communication, encompassing delivery of convincing messages, exuding confidence, and displaying expert knowledge, were identified by farmers as key facilitators of trust. Messages emphasizing the benefits of GM crops sometimes positively influence attitudes towards GMOs and preferences for GM products (Pham & Mandel 2019; Sleboda & Lagerkvist 2022; Stanton et al., 2021). Transparent communication is important to helping build trust (Wu et al., 2020). Self-efficacy and confidence in messengers' abilities are some of the most important traits science communicators need to succeed in convincing others to adopt new technology (Davies & Horst, 2016).

Benson et al. (2020) identified integrity - defined as the consistency between an individual's words and actions - as one of the key facilitators of trust. The scientists' delivery of effective messages was given more credibility when the practical demonstration fields confirmed their assurances that GM cowpea technology could control the pests. The use of demonstration plots is a reliable approach to encourage knowledge transfer (Burton, 2020; Sutherland & Marchand, 2021). Trust in agricultural biotechnology tools and its promoters is enhanced when expectations of the technology are met, promoters display competence, and tangible, beneficial results are seen (Ezezika & Oh, 2012). Further, the building of a collaborative relationship, including frequently visiting the farmers and having open conversations about the technology, was effective in helping build trust and encourage use of the GM seeds. This agrees with the observation by Ezezika et al. (2012) that farmers, as the end-users of GM technology, should be engaged from project inception through implementation, to build trust. These regular visits likely helped create the sense of a shared goal and vision between both parties, thus encouraging trust.

Limitations of Study

This study focused mainly on farmers in the northern part of Ghana who planted GM cowpea seeds under a pilot project. The findings do not encompass several other groups of farmers in the northern part of Ghana who have not planted GM seeds, and the larger population of farmers in the middle belt and southern part of the nation. Also, the study specifically engaged farmers for their perspectives on trust facilitators but did not explore the perspective of the scientists, making the results unidirectional. Finally, several years had passed between the time some of the farmers engaged the scientists on GMOs and the time these interviews were conducted. Challenges with recall may have emerged as the farmers recounted their experiences (Rogers, 2003).

Recommendations

Based on the above, we recommend that scientists seeking to introduce farmers to new technologies use intermediaries the farmers trust, set up demonstration fields to show the technology in action, communicate effectively, encourage peer validation, and build collaborative relationships, to encourage trust. Efforts also need to be made to reduce the risks associated with the technology. Extension services should thoroughly examine the integrity and potential of scientific innovations, collaborate with research institutions to scientifically validate the effectiveness of new tools and innovations, and test them under local conditions before dissemination to farmers (Antwi-Agyei & Stringer, 2021; Danso-Abbeam, 2022; Davis et al., 2012; Lai Nguyen et al., 2020). We also recommend that technology diffusion projects prioritize the involvement of public sector scientists. The activities of industry and private sector actors in efforts to commercialize GMOs encourage the public's and farmers' mistrust of new technologies (Ezezika et al., 2012). The involvement of public sector scientists in promoting GMOs in the northern regions of Ghana appears to have resulted in an opposite outcome where

trust was built. We therefore recommend robust public–private partnerships in future projects. We also recommend integrated and more collaborative approaches to technology dissemination by GMO technology producers. Sutherland and Marchand (2021) contended that farmers are now less receptive to the linear model of technology transfer and more inclined toward interactive networking systems such as the Agricultural Knowledge and Information Systems (AKIS). AKIS recognizes that farmers interact with multiple stakeholders, including researchers, extension agents, fellow farmers, input suppliers, and policymakers. This multi-stakeholder approach acknowledges that farmers draw on a range of sources for information and knowledge in arriving at decisions.

Finally, we recommend that future studies examine trust building from the perspective of scientists introducing farmers to GMOs, beyond this study's focus on farmers' perspectives. Also, quantitative studies that gauge farmers' and the public's perceptions of GMOs are needed in Ghana and likely elsewhere. Such studies could provide reliable data on whether a larger public acceptance of GMOs exists or not and guide policy makers to make appropriate decisions.

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