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RESEARCH

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Exploring farmers attitudes towards genetically modified crops in northwest Bangladesh on the ground of epistemic emotions and cognitions

Md. Hafiz Iqbal[1*]

Abstract

All GM crops fall into either the herbicide-tolerant (HT) or insect-resistant (IR) category. These crops play a crucial role in feeding the global population and ensuring food security for a larger number of population. However, the extent to which current assessments of supply-side effects inform food policy and cultivation decisions remains unclear. To advance knowledge in this area, it is essential to address existing evidence gaps and methodological design issues, which will influence the direction of future research. This study focuses on epistemological preferences among farmers in nortwest Bangladesh, aiming to modestly guide some direction for GM crops cultivation. The findings from the study reveal three distinct attitudinal discourses among investigated farmers. Some farmers are inclined to be positive toward the cultivation of GM crops, expecting benefits. Another group is more cautious, wary of the potential risks associated with GM crops but still likely to be reluctant adopters. A third group demonstrates a somewhat fatalistic perspective toward adopting GM crop cultivation, as revealed through the use of Q methodology. These findings contribute significantly to the ongoing GM debate by elaborating on the views of farmers from these three distinct groups and informing the design of policies related to GM crops.

Keywords Genetically modified organism, Farmer perception, Q-methodology, Farming practice, Food security

Introduction

When the Green Revolution occurred between the 1960s and 1970s, Asian farmers rapidly adapted to new wheat and rice varieties (Herring and Paarlberg 2016). During the period from 1966 and 1998, this agricultural revolution significantly increased crop productivity by 82% (Pingali 2012). The International Rice Research Institute (IRRI) subsequently created and introduced enhanced rice cultivars in more than 70 countries (Bin Rahman and Zhang 2023). By the 1980s, mproved varieties of maize, soybeans, cotton, sorghum, millet, barely, and cassava had been developed. In total, over 8000 novel seeds were created for at least 11 different crops (Arata et al. 2020).

Empirical studies demonstrate that without the utilization of these varieties, the annul crop output in low- and middle-income countries in 2000 would have decreased by 16–20%, and the cost of food and feed would have risen by 35–56% (Evenson and Gollin 2003).

The genetically engineered (GE) crops revolution represents a special case within the Green Revolution. Under such groundbreaking practices, GM crops are commercially planted and used primarily for industrial purposes and animal feed, rather than for direct human consumption (Herring and Paarlberg 2016). For instance, approximately 98% of soybeans and 88% of

*Correspondence:
Md. Hafiz Iqbal
vaskoriqbal@gmail.com
[1] Department of Economics, Government Edward College, Pabna 6600, Bangladesh

maize are utilized either as animal feed or as an industrial feedstock for ethanol production, while cotton serves as a fiber source in the United States (Koçar and Civaş 2013).

The GE field, in conjunction with agricultural biotechnology, plays a pivotal role in developing genetically modified (GM) seeds and crops for farmers (Herring and Paarlberg 2016). Consequently, 1.7 million hectares of land were utilized for commercially grown GM crops in the United States in 1996 (James 2004). Since then, the adoption of GM crops has steadily increased worldwide, and the cultivation area of GM crops has expanded to nearly 190 million hectares by the end of 2017, with 53% of the GM crop hectares being grown in poorer nations (Herring and Paarlberg 2016).

Despite this widespread expansion and adoption of GM crops, there persist criticisms, questions, and public debates regarding the controversy surrounding the risk of GM crops on human health (Lore et al. 2013; Price 2021). GM crops face fierce criticism in several number of member states of the European Union (EU) and Japan (Bernauer and Meins 2003). Additionally, African countries harbor a negative impression of GM crops (Jacobsen et al. 2013).

However, it is important to note that such criticism and public debates lack strong evidence of health risks directly generated by GM crops. According to Herring and Paarlberg (2016), the risk remains indeterminate because there is currently no proven hazard from GM crops that would allow for the construction of a probability distribution of risk. Furthermore, predicting the future effects of GM crops on public health remains elusive. From this perspective, the risk associated with GM crops can be considered socially constructed, existing in imaginary or or prophylactic terms (Gupta 2011).

The information availably in society regarding the uncertainty, risks, and benefits of GM crops remains unclear. There is inadequate understanding of the demand and supply side effects resulting from the adoption of GM crops innovations. Farmers in Bangladesh exhibit varying behavior toward the cultivation of GM crops. Given this context, clear policy guidelines are necessary for GM crop cultivation.

The study contributes to GM crops research in low-income countries in two ways. First, we apply the Q methodology to explore the attitudes of some farmers toward GM crops in-depth. Second, the study bridges the gap between theoretical understanding and practical implementation, offering a nuanced perspective on GM crop cultivation in Bangladesh. The study explores epistemological preference among farmers in nortwest Bangladesh, aiming to modestly guide some directions for GM crops cultivation.

The remainder of the paper is structured as follows: The next section describes the existing state of knowledge. Section "Method" provides the methodology. This is followed by the presentation of results in section "Results", and discussion in section "Discussion". section "Conclusions" concludes.

Existing state of knowledge

GM crops raise controversial issues due to uncertainties about their long-term effects on health, environmental concerns, abd ethical considerations. Vega Rodríguez et al. (2022), for example, have reported that GM crops are not free from controversies because of insect resistance and potential health risks, leading to skepticism and partial bans in some countries. Hall (2008) argued that ongoing debates of GM crops focus on allergenic properties and impacts on biodiversity. Supporting this issue, Herring and Paarlberg (2016) focused on the demerits of GM crops as they reported GM crops have a certain set of similar Known future hazards, such as potential health risks and environmental concerns, insectct resistance, and the emergence of superbugs. However, GM crops offer benefits by reducing chemical use in farming and improving food security through increased productivity (Brookes 2022). All GM crops fall into two categories: herbicide-tolerant (HT) or insect-resistant (IR), both of which are essential for commercial agriculture (Macnaghten and Habets 2020). GM crops have contributed significantly to food security and fiber production, benefiting a larger population and providing feed for animals (Muzhinji and Ntuli 2021). Thess crops have reduced the need for pesticides, increased crop yields, boosted income, lowered food production costs, and enhanced nutrient content and food quality (Kavhiza et al. 2022). For instance, GM technology has led to a 37% reduction in chemical pesticide use, benefiting both farmers and the environment (Gbashi et al. 2021). Collectively, GM crops have increased global food production by nearly 1 billion tonnes, resulting in staggering farm income gains of US$ 261.3 billion from 1996 to 2020 (Brookes 2022).

The cultivation, marketization, and utilization of GM crops are significantly influenced by political economy instruments and regulatory issues (Ikpe et al. 2024). The adoption and regulation of GM crops vary across different countries and regions, reflecting a complex interplay of policies, economic factors, and public perceptions (Woźniak-Gientka et al. 2022). In some regions, such as the European Union (EU) countries, there is a common scenario where the planting of GM crops faces restrictions due to governmene and non-government initiatives and policies (Dibden et al. 2013). However, there are exceptions,, Finstance, farmers receive permission on a smaller scale to cultivate GM crops in South Africa, including cotton (Azadi et al. 2016). Burkina Faso and Sudan, states of Sub-Saharan African countries, grow transgenic Bt (Bacillus thuringiensis) eggplant and cotton (Ratnadass 2020). A few South and Southeast Asiaan countries also have similar experience to cultivate such crops. For example, Bangladesh cultivated Bt cotton and Bt eggplant, while India and Pakistan frequently grown Bt cotton (Quamruzzaman 2021). Additionnaly, the Phillippines cultivated yellow maize (Herring and Paarlberg 2016). In contrast, some countries in Latin and North America, as well as Australia, have embraced GM crops more extensively (Lapegna and Perelmuter 2020). Approximately, 91% of the global GM crops area is covered by countries such as the USA, Canada, Argentina, Mexico, Brazil, and Australia (Dowd-Uribe and Schnurr 2016).

Farmers' preferences, attitudes, and beliefs significant influence the cultivation of GM crops. Understanding these multifaceted factors is essential for promoting responsible and informed adoption of GM crops across different region and cultures (Pratesi et al. 2021). Finucane and Holup (2005) reported farmers' choices significantly impact the cultivation of GM crops in both the United States and Europe. Apart from fermer choices, several other dimensions play a crucial role in cultivation of GM crops. For example, eeconomic status, income level, and social context affect farmers' decisions to cultivate GM crops. Additionally, cultural norms, values and traditions, fermers' willingness to cultivate GM crops, involuntary exposure, consideration of ecological consequences, and legal aspect are also affect farmers' preferences to cultivate GM crops (Frewer et al. 2004; Purchase 2005).

Assessment and exploration of farmer attitudes toward GM crops are complex and contentious issues (Mauro et al. 2009). In these cases, the Q methodology is a decent and reliable approach because of its compression ability between groups (Chatterji et al. 2015). This methodology is currently applied in watershed management (Focht 2002), restoration of forests (Burns and Cheng 2007), waste management (McNicholas and Cotton 2019), and farming practice (Vecchio et al. 2022).

While existing studies investigated farmers attitudes toward GM crops, there remains a gap in understanding how epistemic emotions and cognitive factors influence these attitudes especially in the context of northwest Bangladesh. Epistemic emotions, such as trust, uncertainty, and perceived knowledge, play a crucial role in shaping individuals' perceptions of novel technologies. Additionally, cognitive factors related to risk perception, self-efficacy, and perceived benefits may significantly impact farmers' acceptance or rejection of GM crops. Our study highlights these issues and tries to minimize this existing gap.

Method

Study area

The site selected for our study is Ishwardi *Upazila* (the smallest administrative unit of Bangladesh) in Pabna district, Bangladesh. It is situated between 24°03′ and 24°15′ north latitudes and 89°00′ and 89°11′ east longitudes (Uddin et al. 2018). It has a surface area of 246.90 sq km (Fig. 1). Ishwardi is the largest crops-producing region in Bangladesh. The cultivation of corn crops is gradually decreasing in the country, and on the contrary, the cultivation of vegetables and fruits is drastically increasing in Ishwardi *Upazila*. As the cultivation of vegetables and fruits (such as lichi, guava, lemon, banana, citrus fruits, plum, potatoes, cabbage, cauliflower, eggplant, radish, bottle gourd, okra, and country or Indian beans) is comparatively profitable, the farmers of this region tend to cultivate vegetables and fruits instead of cereals or corn crops (such as paddy, wheat, and maize). We chose this site for two reasons. First, a group of farmers has great interest in GM crops for prompt production and reduction of environmental degradation through lower or no utilization of pesticides and organic and inorganic fertilizer. Second, another group of farmers has less interest in GM crops because of health risks. For a major and pertinent empirical assessment of GM crops, a bridge between these two groups must be made, which requires a sufficient understanding of epistemology.

Epistemological approach

When a factual question between two groups of farmers about GM crops arises, it is essential to take a stand in favour of or against GM crops. An epistemological approach helps to take a clear stand on this particular issue because of the epistemological status of social science as either a factual question that could theoretically have a scientific response or a normative question that cannot have an empirical answer (Creswell 2014). According to Blaikie (2007), epistemology is the theory or science of the method or grounds of knowledge, which can also refer to a set of claims or presumptions about how it is possible to learn about reality, how what already exists can be known, and what can be known, as well as the requirements that must be met for something to be referred to as knowledge. It deals with how people obtain, comprehend, defend, and apply knowledge (Greene et al. 2016). More specifically, individuals engage in epistemic cognition when they activate personal beliefs about the nature of knowledge and knowing (i.e., epistemic beliefs), define epistemic aims and criteria for knowing, and use evaluation and justification strategies to address issues

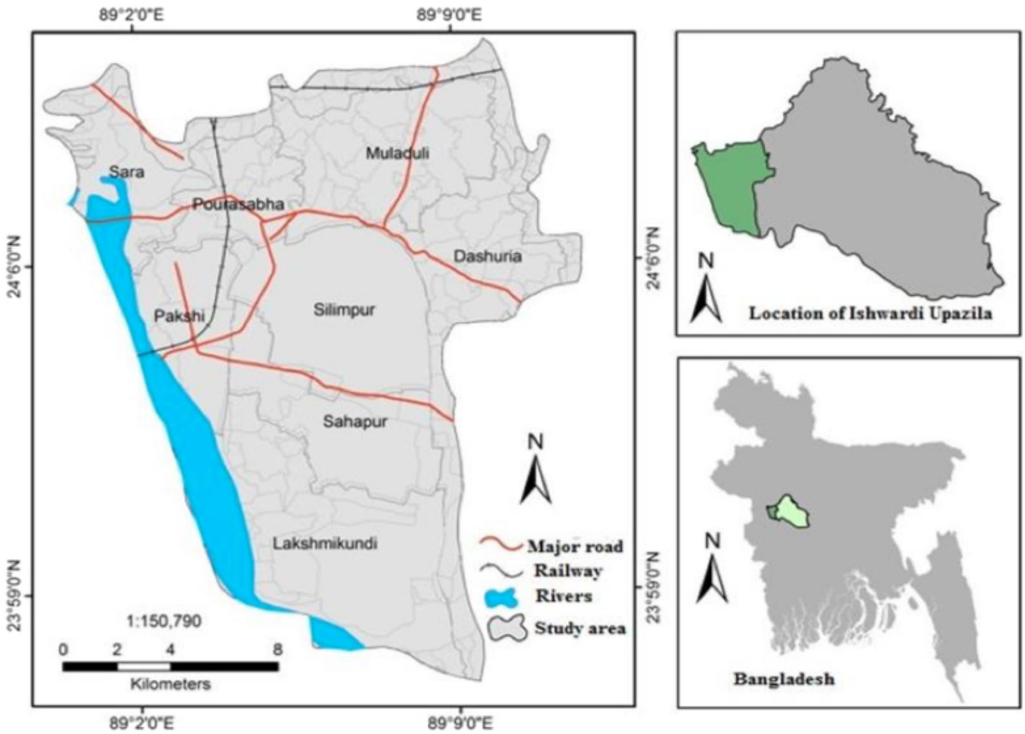

Fig. 1 Map of study site. *Source* Adapted from Islam et al. (2015)

of the nature of knowledge and the process of knowing (Muis et al. 2021). It helps expose respondents' critical thinking. Under this approach, we examined the role of epistemic cognition on critical thinking when contending with conflicting information about GM crops and the report respondents' epistemic beliefs about GM crops through mixed method research (MMR).

Mixed method research

We used methodological pluralism, or methodological triangulation, or MMR, for proper empirical assessment. MMR are strategies and approaches for conducting research that range from general hypotheses to specific techniques for gathering, analyzing, and interpreting data. It is important that qualitative and quantitative techniques are not polar opposites, inflexible classifications, or dichotomies. Instead, these are various points along a continuum (Creswell 2014). Due to the fact that it combines aspects of both qualitative and quantitative techniques, MMR falls somewhere in the middle of this spectrum.

MMR is an approach to inquiry that involves collecting both quantitative data (KII, FGD, open-ended questions, and qualitative interview questions) and qualitative data (survey through a questionnaire, close-ended questions, and quantitative hypotheses), integrating the two forms of data, and using distinct designs that may involve philosophical assumptions and theoretical frameworks. The core assumption of this form of inquiry is that the combination of qualitative and quantitative approaches provides a more complete understanding of a research problem than either approach alone. It is suitable for pragmatic knowledge claims and appropriate for sequential, concurrent, and transformative issues.

Q-methodology

The Q-methodology is a psychological approach developed to explore people's subjectivity, consider diverse viewpoints on a subject, and group responses (Pinillos et al. 2021). Rather than describing an idea population in isolation, it connects ideas. According to Webler et al. (2007), it is the most suitable method for examining the attitudinal forms within a target group and exploring subjective phenomena. In this methodology, participants sort statements using cards with printed statements on a board, following a predetermined distribution for sorting (refer to Table 2 for details). Participants score comments related to a specific subject based on their own observations, beliefs, and judgments, aligning with the scientific approach (Zabala et al. 2018).

Our statements about GM crops were derived from opinions shared by farmers during semi-structured and open-ended interviews conducted before the sorting exercise. When similar statements load heavily on the same component, choices are clustered based on factor analysis, aiding interpretation and narrative development (Dieteren et al. 2023).

The steps of the Q-methodology of our study are as follows: We first determined the study area and explored the farmers' nature. The second stage covered the collection of GM crops-related discourse. The third stage dealt with farmers interview to grasp their perceptions towards GM crops, develop concourses, and determine sub-samples (including benefits believers, risk-averrers, and traditionalist).

Open-ended and semi-structure interview

The third stage is treated as the open-ended and semi-structured interview stage. In this stage, the concourse related to GM crops adoption are collected from document reviews and personal interviews based on a set of few open-ended questions designed specifically to elicit statements. Relevant documents were downloaded from Google Scholar, while personal interviews occurred in different villages of Ishwardi *Upazila* between December 15 and 29, 2021.

Sample selection

The fourth stage is known as the sample selection stage. All selected farmers are asked to rank or sort the collected statements using a scale in this stage. The flow of information surrounding any topic in a Q application is known as the concourse, where a collection of statements is drawn for the concourse and is then sorted.

Although these responses provide some insight on farmer attitudes, the application of the Q approach allows for a more in-depth examination of their opinions. To do that, we collected a set of 231 statements, one from observational studies and printed materials, and the rest from interviews. The issue-based statements are placed on the horizontal axis, while the technical statements of GM crops are presented on the vertical axis. We proposed a total of 36 statements for the Q-sample, and these 36 statements are known as the Q-sorts (Table 1).

The statement sorting exercise was undertaken in December 2021 and January 2022, respectively, in different villages of Ishwardi *Upazila*. Q-studies usually follow stratified sampling (Pinillos et al. 2021), but given the contemptuous nature of our topic, this study decided to follow a purposive and random sampling technique to avoid the sole inclusion. Our selected respondents ($n = 423$) during the survey was split into three groups (such as benefits believers (n_1), risk perceivers (n_2), and fatalist (n_3) i.e., n $(423) = n_1(178) + n_2(160) + n_3(85)$. Respondents were selected based on their perceptions towards the advantages and disadvantages of GM crops.

Table 1 Matrix for categorization of statement

Statement topic	Technical issues	Problem-based issues
Wildlife protection and pest control	5	1
Input form Industrial agriculture and technology	2	1
Risk potential and safety	4	7
Cultivation restriction	3	4
Miscellaneous views	1	8

Q-sorting and wrapping-up discussion

This fifth stage is known as the Q-sorting and wrapping-up discussion. During the survey in the fifth stage, all respondents were provided with (1) 36 cards, each containing a statement and its number; (2) an instruction bar with a quasi-normal distribution; and (3) an answer sheet to keep the rank order. Respondents were then requested to read all statements, sort the cards according to the extent to which they disagreed or agreed with them using a standard Likert scale (strongly disagree: −3 to strongly agree: + 3), and place the cards on the instruction bar. The Q study sorting schemes are presented in Fig. 2. Respondents were also interviewed about their own experience with GM crops, concurrent problems, and opinions about GM crops.

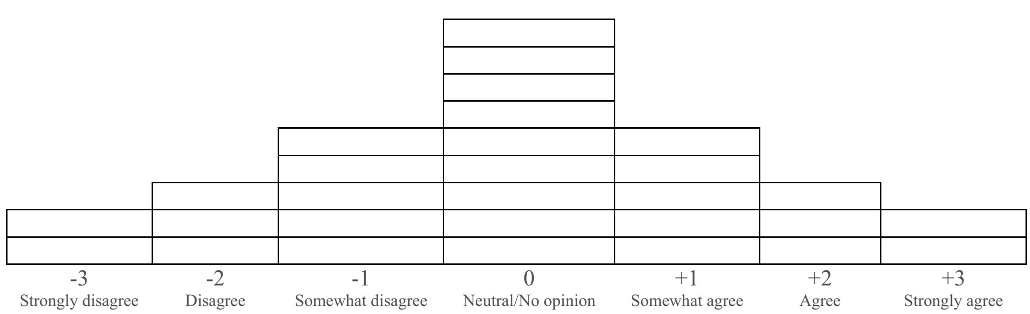

Fig. 2 Guide bar with quasi-normal distribution

Factor analysis

The study extracted a few common sorts using statistical analysis. In the last stage, we concluded by describing and interpreting these common sorts. The analysis of the 'sort' using PQMethod in this stage is Q-methodology process (Schmolck 2002). The different attitude groups that are present in the broader discourse surrounding the topic of the inquiry are represented by the defining types that emerge from factor analysis. The four unrotated factors in this investigation are created using the principal component analysis (PCA), which produces eigenvalues larger than 1. The factors were then rotated using Varimax rotation, allowing us to investigate two-factor, three-factor, four-factor, and five-factor solutions for sort rotation. We can evaluate the three factor groups or discourses because the model is statistically significant, justifiable, and provides the most coherent interpretation of the sorts.

Following Mahlalela et al. (2022), we considered the factor loading of each Q-sort to detect the most pertinent factor at the $p < 0.10$ level of significance with 2.58 times the standard error. Under this process, $1/\sqrt{N}$ is applied to estimate the standard error for a factor loading, where N equals the number of statements (Christensen and Golino 2021). The standard error for each loading in our investigation is estimated at 0.43 ($2.58 \times 1/\sqrt{36}$) and is presumptively loaded considerably on the pertinent factor. Other sorts are not included in any of the three factors in the study, thus we did not include them in our further analysis.

Results

A total of 423 farmers participated in interviews and surveys through questionnaires. All interview and survey questions were approved by a group of agronomists and agro-biotechnologists in Bangladesh. Respondents were catagorized into benefit believers, risk-averse individuals, and traditionalists based on their positive, negative, or neutral notions about GM crops.

Statement scores are the foundation for the explaining the factors. For each interpretation, the statement score is first calculated as a z-score and then transformed into the original Q-sort value format (ranging score from −3 to +3) (see Table 2 for additional information). There are 36 statements in total. Among these, 15 statements related to technical issues, while the remaining 21 pertain to problem-based issues. Positive ratings for statements indicate a farmer's favourable perception, negative numbers reflect their negative perception, and a zero rating indicates neutral stance toward GM crops.

Factor A-Benefit believers ($n_1 = 178$)

The findings shown in Table 2 imply that factor A encompasses a viewpoint that is predisposed to be favorably disposed toward the idea of growing GM crops. Due to its role in popularizing GM crops, this factor raises some questions concerning social mobilization (statement 1, converted factor score + 3). Due to technology improvement (15, + 2) and input support from industrial agriculture (16, + 1), farmers with this factor are likely to be accepted to produce such crops. A higher profit margin (20, + 3), a lower cost of production (30, + 2), subsidies on necessary input (6, + 3), leveling of GM crops (5, + 3), experience (8, + 2), no difference between GM and non-GM crops (12, + 1), market demand (24, + 1), natural genes (29, + 3), and pesticide- and formalin-free crops (36, + 3) are all necessary for cultivation in addition to the popularity of GM crops. Benefits believers factor group specifically stated a preference for the production of GM crops due to their benefits for the environment (11, + 1), supply chain management (19, + 2), food security (22, + 3), control of plant diseases (25, + 3), good farming practices (26, + 2), and benefits for insect, wildlife, and birds (27, + 3), and price stability (32, + 2).

This discourse expresses a point of view that is unconcerned with impressions of the current cultivation scenario of GM crops in all cultivable places (7, 0). Farmers in this group also showed an interest in reducing fertilizer use and its negative consequences on available employment opportunities and current farming techniques (3, − 1; 9, − 2). In this group, statements 12, 15,16, 29 and 36 are technical issues and the rest statements are problem-based issues.

Benefit believers advocate GM agricultural growing practices because they value financial gain over the welfare of people. Interview talks did in fact show that farmers have discovered via trial and error how to cultivate more GM crops at a reduced cost of production. The farmers in this group are generally more interested in growing GM crops.

Factor B- Risk-averrsers ($n_2 = 160$)

Although this factor's attitude is far less likely than factor 1 to be in favor of GM crops, it is not necessarily against them (statement 26, converted factor score + 2). The views of this group are strongly focused on cultivation restriction, impact on agricultural farming, wildlife and insect, GM-free Bangladesh, market restriction, support from technology, input support from industrial agriculture, supply chain management, unknown risk, insect, wildlife, and bird protection, protection of native crops, health risk, and consumer perception (7, + 3; 9, + 3;

Table 2 Q-sorts value for each statement

TI ($n=15$)				
2	Cultivation of GM crops are essential to control pest and grasses	2	1	1^{***}
3	No need fertilizer to produce GM crops	-1^{*}	-2^{**}	3^{*}
4	If I do not apply pesticide, the yield of GM crops may reduce	-2	0	1^{**}
9	Farmers would be impacted by issues brought on by the introduction of GM crops	-2^{**}	3^{**}	1
10	I have no idea how GM crops might affect wildlife and insects that lives on farms	0	1^{***}	0^{*}
11	GM crops have positive impacts on our environment	1^{*}	0^{*}	2^{**}
12	Eating crops that are GM or not makes no difference to me in terms of safety	1^{*}	2	1^{*}
15	I think it's better to cultivate GM crops because we should accept technology	2^{**}	2^{*}	2^{*}
16	Industrial agriculture provides a significant portion of the input for GM crops	1^{***}	1^{***}	1^{**}
18	Less spraying for GM crops is essential to protect wildlife	3^{***}	0	-1^{*}
28	GM crops are responsible for exterminating native crops species	-1	2^{*}	-2
29	Natural genes are added to GM plants are ok but not gens from other species	3^{**}	2^{**}	1
31	Health risk is strongly associated with GM crops	1	1^{***}	-2^{*}
33	I cannot adopt GM crops because I do not have enough cultivation knowledge	0	-1	2^{**}
36	I am happy because pesticide-and formalin-free crops are possible under this cropping system	3^{*}	-3^{**}	0^{*}
PBI ($n=21$)				
1	Social mobilization is necessary to popularize GM crops	3^{*}	3^{**}	3^{***}
5	Levelling on GM crops is significant for consumer buying decisions	3^{***}	1	1^{**}
6	Subsidy on essential input of GM crops	3^{***}	0^{*}	1^{***}
7	We should restrict cultivation of GM crops to all cultivable areas	0^{*}	3^{**}	3
8	We could not cultivate GM crops correctly because we had no experience	2^{*}	2	0
13	I want to see GM crops free Bangladesh	-2	3^{***}	2^{**}
14	We should avoid GM crops because our existing market does not allow such crop	-3	3^{*}	0^{**}
17	GM crops frequently have lower market prices	2	0	0
19	GM crops allow for effective supply chain management	2^{**}	2^{*}	0^{***}
20	I would choose to grow GM crops if there was a higher profit margin for doing so	3^{***}	-3	0
21	Unknown risks to our grandchildren are the potential outcomes of GM crops	-2	3^{***}	-1
22	GM crops can facilitate food security	3^{***}	-2	-2
23	We should ban GM crops in our locality	0	0^{*}	-1
24	I might be encouraged to grow GM crops if there is demand from consumers	1^{***}	-1	2^{**}
25	The introduction of GM crops in Bangladesh enables the control of disease	3^{*}	-3	2^{***}
26	The introduction of GM crops into Bangladesh would be good for farming practice	2^{**}	2^{*}	-1^{*}
27	GM crops are likely to cause no problems with insects, wildlife, and birds	3^{*}	3^{***}	2^{*}
30	Farmers would benefit from lower costs and increased yields with GM crops	2^{***}	0	0
32	I think GM crops would be good for price stability	2^{*}	0	1^{*}
34	We could not cultivate GM crops because consumers have a negative perception	1	2^{*}	3^{***}
35	My relatives and neighbours will support me if I adopt cultivation of GM crops	2	0	2^{*}

Factor A = benefit believers, B = risk averrers, C = Fatalist. $^{*}p<0.01$, $^{**}p<0.05$, $^{***}p<0.10$

TI stands for technical issues, and PBI stands for problem-based issues

10, +1; 13, +3; 14, +3; 15, +2; 16, +2; 19, +2; 21, +3; 27, +3; 29, +2; 31, +1; 34, +2).

Another important viewpoint is found in opinions of fertilizer utilization and pesticide- and formalin-free crops, of which this group was not in favor (3, −2; 36, −3). Statements 3, 9, 10, 15, 16, 29, 31 and 36 are related to technical issues. On the other hand, 7, 13, 14, 19, 21, 27 and 34 are concrens of problem-based issues. Bangladeshi consumers always prefer fertilizer-, pesticide-, and formalin-free crops because of the reduction of health risks. Disagreement with the practice of fertilizer, pesticide, and formalin-free crops implies no faith in GM crops with no fertilizer, pesticide, or formalin. Additionally, there are a few statements with which this discourse has a neutral viewpoint. These are related to subsidy (6, 0), positive impacts (11, 0), and avoidance of GM crops (23, 0).

This farmer group has a neutral attitude towards positive impacts on our environment and has refused to change from traditional farming practices to GM crops-based farming. In addition, farmers in this group viewed GM crops adoption as responsible for health hazards.

Factor C-Traditionalists or fatalist ($n_3 = 85$)

Factor C results describe a somewhat fatalist attitude towards GM crops. The statements of this group are strongly highlighted on social mobilization (statement 1, converted factor score + 3), pest and grasses control (2, + 1), no utilization of fertilizer (3, + 3), necessity of pesticide (4, + 1), leveling (5, + 1), subsidy (6, + 1), good environment (11, + 2), safety (12, + 1), restriction impose (13, + 2), support from technology (15, + 2), input support from industrial agriculture (16, + 1), consumers demand (24, + 2), disease control (25, + 2), good for insect, wildlife, and birds (27, + 2), price stability (32, + 1), price stability (32, + 1), cultivation knowledge (33, + 2), consumers perception (34, + 3), and support from relatives and neighbors (35, + 2).

Other statements, such as opinions on wildlife protection from spray (18, − 1), good farming practice (26, − 1), and health risks (31, − 2) are not in favor of this group. Furthermore, there are a few statements in this discourse that take a neutral stand. These are connected with having no farming experience with GM crops (8, 0), no idea of wildlife and insect protection (10, 0), no market access (14, 0), lower market price of GM crops (17, 0), supply chain management (19, 0), higher profit margin (20, 0), lower production costs and higher productivity (30, 0), supply chain management (19, 0), and pesticide- and formalin-free GM crops (36, 0). All these statements are combinations of problem-based, and technical issues.

This farmer group is economically viable, most likely because it does not clearly understand the benefits and drawbacks of GM crops. Additionally, this group actively advocated for the viewpoint of epistemic emotions and cognitions that subsidies and popular mobilization are crucial for advancing the cultivation of GM crops. This notion is strongly supported by the findings of interview. According to interviews, subsidies and education initiatives are more important policy tools for improving farmers' knowledge on how to grow GM crops. These requirements indicate that this farmer group is likely to produce better GM crops in terms of such measures.

Consensus statement

There are a number of declarations of unanimity among all three elements, despite the fact that the factors clearly represent diverse perspectives. The common viewpoint of the farmers is reflected in the consensus statements. It is possible to conclude that social mobilization, technological advancement, and input support from industrial agriculture can promote cultivation of GM crops in Bangladesh based on the statistically significant and indistinguishable z-score, the fact that all factors ranked in the same direction within a single statement, i.e., 1, + 3; 15, + 2; and 16, + 1 in Table 2, and the fact that all factors were statistically significant and indistinguishable. Statement 1 is related to problem-based issues. Likewise, statements 15 and 16 ared derieved from technical issues. Farmers of all groups strongly require awareness program to popularize cultivation process of this crops. They also require adequate training or knowledge about the used technology of GM crops. Such a training program helps to get proper preference scenario of GM crops cultivation.

In our analysis, every element showed a cautious attitude about the potential introduction of GM crops. The degree of caution and worry over health risks and the desire for future rewards distinguish them from one another. Factor 1 defines a discourse that is less risk-averse, more pro-technical, and more confident in the advantages that GM crops are anticipated to experience as a result of technological innovation. Factor 2 depicts a discourse that is more open to different options for future cultivation practices and less assured of their potential benefits. Factor 3 points to a basically fatalistic mindset that isn't blind to prospective risks and rewards but also isn't particularly biased either way.

According to the estimated converted factor score, factor 1 farmers exhibit pragmatism, mild progressivism, and environmental awareness. To benefit more from GM crops, they would like greater government support and demand. Farmers that fall under factor 2 are, in contrast, receptive to market demand, anxious about benefits from the introduction of GM crops, and wary of loss. They are skeptical about an unstable market and pay. Similar to factor 2, traditional agricultural communities and parochial traditions influence the farmers in factor 3. Concerns shared by this group include the quality of GM crops, an unstable market, a lack of flexibility, and social marginalization.

The research on GM crops predominantly originates from the Global North. Efforts should be made to address the specific needs and contexts of Bangladesh. However, adopting this cultivation practice is challenging due to the heterogeneous preferences of the agrarian society in Bangladesh, the northwest region is no exception. For example, benefit believers perceive GM crops as a pathway to improve agricultural productivity, increase income, and enhance food security. They also trust scientific evidence, emphasizing the potential benefits of GM crops. Farmers in this group believe that social mobilization, technological support, and input assistance are essential for popularizing the cultivation of GM crops.

Discussion

The Q methodology is not without flaws, including bias in participant selection, lack of control over external variables, methodological transparency and theoretical adaptation, difficulty quantifying changes over time, and a narrow scope for investigating complicated subjects (Sneegas et al. 2021). Notwithstanding these drawbacks, the Q technique is well evaluated from an epistemological perspective. Even though crop farming research is using the Q technique more and more, it still seems relatively innovative because it is regarded as a potent instrument for examining the subjective dimensions of crop farming research (Vecchio et al. 2022). In epistemological research, such as those involving GM crops in Kalomo district, Zambia, participants' attitudes and perceptions may be influenced by a variety of external circumstances, which may be sufficiently controlled for using the Q methodology (Siangulube 2023). It is intended to take a snapshot of farmers who are growing GM crops, which facilitates tracking the evolution of these farmers' attitudes and views over time (Nawaz et al. 2023).

We asked sampled farmers, using the Q methodological technique, "What do you believe are the advantages and disadvantages of GM crops in your *Upazila*?" during interviews based on epistemic emissions and cognitions. 178 farmers (benefit believers) out of the respondents claimed that GM crops are more advantageous because of their lower cost of production. On the other hand, 160 farmers (or risk aversers) reported worries about negative effects because GM crops clashed with conventional farming practices. The remaining 85 farmers (20%) who identified as fatalists or traditionalists were conflicted.

When asked about cultivation on their farms, out of 423 selected farmers, only 97 (23%) reported cultivating GM-based brinjal. The majority 326 indicated no cultivation practice for GM crops due to negative perceptions (44%) and a fatalist attitude (33%). Additionally, when queried about profit, approximately 85 (20%) of farmers believed that GM crops generate more profit than traditional crops, while the remaining 338 (80%) were uncertain about the profitability of GM crops.

Risk averrers exhibit caution and apprehension, fear, uncertainty, and skepticism surround GM crops. They weigh potential risk, such as environmental, health, and socio-economic-against benefits. Lack of trust in regulatory systems and corporate interests shapes their views. Like the benefit believers, they also argue that social mobilization, technological support, and input assurance are essential for developing cultivation practice of GM crops.

Fatalist perceive GM crop adoption is inevitable, irrespective of their preferences. Their acceptance or rejection of GM crops is influences by external factors beyond their control. This group of farmers have the same notion about the proper coordination of social mobilization, technological support and input availability can improve the condition of GM crops.

Ensuring affordable access to GM seeds is critical. Under the provision of input support, farmers require knowledge on cultivation practices, risk management, and stewardship. Additionaly, investment in irrigation, storage, and transportation infrastructure enhance to mitigate debate about the adoption of GM crops in northwest Bangladesh. The acceptance of GM crops is influence by social mobilization, such as public awareness, engagement, and fermers perception. Awarness program plays a catalyst to popularize the adoption of GM crops in the agriran society in northwest Bangladesh. Technological supports is essential to popularize GM crops. It offers region-specific GM varietis, emphasizing local needs and preferences. It also covers pest resistance, improved yield, and climate resilience.

This results confirms the findings of previous studies (Mishra 2020; Debernardi et al. 2020; Qaim 2020; Clapp 2021; Kedisso et al. 2023) and it is consistent with the self-reported reasons who debate occure on GM crops. Mishra 2020), for example, reported that massive social mobilization can contribute to reduce criticism and promote farming practices of GM crops when farmers of India are against this farming practices. On the other hand, technological supports can improve yielding capacity of GM crops. Debernardi et al. (2020) reported that expression of a fusion protein combining wheat Growth-Regulating Factor 4 (GRF4) and its cofactor GRF-Interacting Factor 1 (GIF1) substantially increases the efficiency and speed of regeneration in wheat, triticale and rice and increases the number of transformable wheat genotypes. They further added that *GRF4–GIF1* induced efficient wheat regeneration in the absence of exogenous cytokinins, which facilitates selection of transgenic plants without selectable markers. Qaim (2020) pointed out that new plant breeding technologies (NPBTs), including genetically modified and gene-edited crops, offer large potentials for sustainable agricultural development and food security while addressing shortcomings of the Green Revolution. Like the social mobilization, and technological support, input availability is also essential to adopt GM crops. Clapp (2021) reported that glyphosate- based agricultural herbicides have become so entrenched in farming of GM crops instead of chemical herbicides. Seed availability, essential fertilizers, irrigation facility, and labor availability are essential to promote GM crops (Kedisso et al. 2023).

Conclusions

In this study, we revealed different perceptions among farmers regarding adoption of GM crops. Some respondents recognized the advantages of GM crop. However, they expressed a desire for a more flexible policy framework to introduce GM crops. Other farmers priotrized fertilizer use restrictions and preferred crops that were pesticide, herbicide, and formalin-free. They were concerned about health and environmental risks accociated with GM crops. A third group of farmers exhibited a mix of indifference towards GM crop. They paid more attentation to using less pesticide and herbicide and were cautious due to their lack of knowledge about GM crops. These varying perceptions stem from a combination of socio-economic-technological factors, problem-based and technical issues, and ideological and political backgrounds. To engage with this diversity of perspectives, consider facilitate dialogue by involving different farmers and stakeholders by social mobilization, highlight the benefits of GM rops through innovative approaches by technological innovation, and ensure access to necessary inputs for successful GM crop cultivation.

It is important to note that our study did not include discussions with sample respondents from a broader study area. Future research in this area could provide more relevant insights into GM crops cultivation.

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MHI wrote the main manuscript text, prepared all tables and figures. The author read and approved the final manuscript.

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Availability of data and materials
The datasets that support the findings of the study are available on reasonable grounds and upon request from the author.

Declarations

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Not applicable.

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