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Women at the forefront: raising awareness of climate-resilient varieties to transform the informal seed trade in Tanzania

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Access to and utilization of quality seeds have been significant challenges facing Tanzania's agricultural sector, especially for open-pollinated crops such as common beans, sorghum, and groundnuts. Marketplace traders purchase grains for sale from farmers who often rely on traditional varieties, which may have lost their effectiveness in combating emerging challenges such as pests, diseases, climate change, and variability. Despite the availability of improved climate-resilient varieties, limited promotional efforts have been made to increase their adoption among marketplace traders, who are mainly women. Moreover, the current promotion and awareness-creation efforts by public and private partners often target smallholder farmers, with limited success in increasing adoption and replacing old varieties. This study explored the preferred approaches by marketplace traders for receiving information about newly released climate-resilient varieties to enable them to switch to selling grains of new climate-resilient varieties. Quantitative data were collected from 657 marketplace traders (372 women and 285 men), and qualitative data were collected from 180 marketplace traders across rural and urban markets, with women comprising 58% of them. Content and ethnographic methods were employed to analyze the qualitative data, while descriptive analysis and a multivariate probit model (MVP) were used to analyze the quantitative data. The findings show that marketplace traders have limited information about the existence of the new climate-resilient varieties but are motivated to receive information about the new climate-resilient varieties due to the associated supply, quality, and yield advantages. Local radio stations, in-person meetings, posters placed in the local markets, and WhatsApp groups are preferred channels for sharing information about new climate-resilient varieties with marketplace traders and some farmers. Due to low smartphone ownership, female marketplace traders preferred phone calls, text messages, local radio, and in-person meetings to access various types of information. A single approach is not a one-size-fits-all solution; it may be effective in some contexts but not in others. Therefore, prioritizing a set of effective approaches that women prefer for sharing information about climate-resilient varieties would be more likely to achieve the intended adoption impacts.

KEYWORDS

climate resilience, women, marketplace traders, in person meeting, local radio, WhatsApp

1 Introduction

The agricultural sector in Tanzania plays a pivotal role in the country's economy, accounting for approximately 28% of the national GDP and employing approximately 65.5% of the workforce. It also provides 65% of raw materials to the industrial sector and 30% of export earnings, serving as a key pillar of food security and rural livelihoods (ASDP II, 2017; Snyder et al., 2020). Approximately 70% of Tanzanians live in rural areas and engage in agricultural activities as their main occupation (Msuya et al., 2018; Wineman et al., 2020). However, smallholder farmers encounter numerous challenges in achieving economic growth through agriculture. One of the challenges includes limited access to quality inputs (Mwimo et al., 2016; REPOA, 2021). Many farmers face difficulties in accessing high-quality seeds, fertilizers, and other essential inputs due to limited information and underdeveloped distribution networks, particularly in remote areas. These challenges hinder their ability to obtain the necessary resources for productive farming.

Additionally, climate variability presents a significant challenge (Mussa, 2020), which greatly affects agricultural production. Farmers are not well-prepared to be resilient to climate change and variability. Although many technologies have been developed to address these challenges, particularly in the agricultural sector, one key technology is the development of new seed varieties. These varieties are designed to withstand the effects of climate change and variability, as well as biotic and abiotic stresses, and are commonly referred to as climate-resilient varieties (Otieno et al., 2021).

Notably, access to and utilization of climate-resilient seed varieties have been significant challenges facing Tanzania's agricultural sector, particularly for open-pollinated varieties (OPVs) such as common beans, sorghum, and groundnuts. Despite these challenges of limited access to and utilization of climate-resilient seed varieties, these crops also face the issue of farmers using old varieties. These old varieties may have lost their effectiveness, especially in combating emerging climate change stresses, such as diseases and insect-like pests, which affect productivity and, consequently, lead to low margins. Moreover, many farmers continue to recycle old seeds for multiple seasons beyond the recommended period. The average yield of common beans in Tanzania by smallholder farmers is estimated to be 0.5 t/ha, while the potential yield under improved varieties and reliable rainfall ranges from 1.5 to 3 t/ha (Hillocks et al., 2006).

Over 60% of farmers purchase grain of these crops as seeds from traders who sell them grain during the harvesting season (Ochieng et al., 2024a). The Tanzania Agricultural Research Institutions (TARI), in collaboration with other development partners, has made significant efforts to develop new crop varieties that are enhanced to withstand emerging biotic and abiotic climate-related stresses. Despite these efforts, the distribution and adoption of newly released climate-resilient varieties, particularly those released within the past decade, have been low and have not reached the expected levels in the community (Ochieng et al., 2024a). Several scaling interventions have had limited success in sustainably supplying quality seeds to farmers. These efforts have been marred by numerous limited adoption cases, mainly due to the lack of a market that traders or aggregators would fill if engaged in the scaling process (Sperling et al., 2021).

Marketplace traders dealing with OPV crops, such as common beans, sorghum, and groundnuts, source grains from smallholder farmers who often rely on old varieties that may have lost their resistance to pests and diseases, as well as their adaptability to climate change. In the Tanzanian marketplace, traders are primarily women, constituting 80% of the marketplace traders. However, the engagement of marketplace traders in the seed system has been neglected and unrecognized, yet they play an important role not only in purchasing and selling grains but also in the informal seed sector (Sperling et al., 2021). In a recent study, 44, 31, and 23% of marketplace traders for common beans, groundnuts, and sorghum in Tanzania are involved in selling informal seeds to farmers (Ochieng et al., 2024a).

Additionally, 60% of smallholder farmers growing these OPV crops purchase grains from traders, including at the marketplace, to use as planting materials during the planting season. This practice has led to a cycle in which the same older varieties continue to circulate between farmers and traders over time (Ochieng et al., 2024a). At the same time, marketplace traders source their grains from farmers (44% for common beans, 53% for sorghum, and 29% for groundnuts), who often lack access to improved varieties for improved productivity (Ochieng et al., 2024a). Thus, it is anticipated that marketplace traders will create a seed demand signal to formal and early-generation seed system actors, and that demand for specific varieties provides a powerful incentive for farmers to adopt new varieties, as they must meet their grain quality standards and provide an adequate/reliable supply (Ochieng et al., 2024b).

Despite the availability of new climate-resilient varieties, limited promotional efforts have been made to encourage their adoption and increase sales among marketplace traders, who play a vital role in engaging both farmers and last-mile consumers, as well as large traders serving as collectors. Limited studies have been conducted to identify approaches for engaging marketplace traders. This study explored the preferred approaches through which marketplace traders, who are predominantly women, can receive information about climate-resilient varieties to encourage them to switch to selling grains of improved climate-resilient varieties and share information with farmers about the newly released climate-resilient varieties and where to source them. Well-informed marketplace traders who purchase grains from farmers can help smallholder farmers obtain information about the newly released climate-resilient varieties and increase their accessibility. Ultimately, this study will aid in scaling projects such as Accelerated Varietal Turnover for Open-Pollinated Varieties (ACCELERATE) by understanding the preferred communication approaches and strategies for engaging marketplace traders, who are currently underrepresented, in efforts to scale up new, improved varieties and increase varietal turnover.

2 Literature review

This study also reviewed existing literature on various approaches and strategies proposed for effectively disseminating information and engaging different target groups within the community, particularly in the agriculture sector, including farmers and marketplace traders. The reviewed literature indicates that while numerous studies have focused on approaches for sharing information with farmers regarding farming productivity, food security, and related issues, there is a notable gap in research on which strategies are effective for engaging marketplace traders. The use of WhatsApp has gained significant popularity in sharing information among various stakeholders in the agricultural sector.

This is because WhatsApp provides a broad platform for users to access information, engage in discussions with fellow stakeholders, and even view and share images related to the information. Numerous scholars, including Bhatt et al. (2020), have shown that WhatsApp is a key way to address the knowledge gap among marginal farmers by providing easy access to information and a platform for discussion, which can be facilitated by involving WhatsApp in farming practices to collect a pool of knowledge in one place. WhatsApp is also a handy social media tool, and it is mostly preferred by farmers, as it plays a critical role in agricultural marketing (Singh et al., 2019). Thakur and Chander (2018) found that the study participants responded favorably to using WhatsApp as a tool for receiving and exchanging agricultural knowledge, deeming it useful and convenient for their needs. Ifeanyi-Obi and Corbon (2023) and Das (2021) note that WhatsApp, one of the social media platforms, plays a vital role in sharing agricultural extension and rural advisory services with farmers amid the new and rapidly changing agricultural extension system.

Studies have also shown that WhatsApp is a suitable approach for sharing information among traders, including marketplace traders. Naneetha (2018) highlighted how WhatsApp empowers small businesses to build customer relationships and become an integral part of their operations. It is further described that WhatsApp is becoming a tool that is driving many small businesses toward a new paradigm shift. This was further supported by Akhmadi et al. (2021). Despite WhatsApp being the preferred approach for information sharing among fruit marketplace traders, there was also a strong and positive correlation between the perceived benefits and the use of WhatsApp for fruit marketing communication.

The use of local radio to share information within the agriculture sector has proven to be one of the vital means of disseminating knowledge to various stakeholders in Africa. With widespread access to local radios in rural areas, local radio serves as an essential communication tool, reaching even the most remote communities, including women who have limited time due to their dominant involvement in productive activities and household chores. Local radio bridges the knowledge gap by delivering real-time agricultural advice. Marketplace traders stay informed about new market opportunities, and policymakers and extension officers use the medium to share policy updates, capacity-building opportunities, and upcoming initiatives aimed at improving the agricultural sector. As shown by Hudson et al. (2017), local radios have an extensive reach, penetrating even the most remote and impoverished communities to disseminate information across Africa. Nyareza and Dick (2012) showed that local radio was the preferred medium of communication for rural peasant farmers. The farming programs are relevant to their own agricultural activities, use their local language and accents, and allow them to contribute to the program content.

Mhlaba and Yusuf (2020) found that local radio is a powerful and widely used medium for mass communication, facilitating the sharing of information with rural audiences across Africa. It is a popular, low-cost option that can be easily accessed by marginalized groups in developing countries. Local radios also significantly contribute to rural development across Africa (Sungu and Kopoka, 2019; Timalsina and Pradhan, 2019; UNESCO, 2023; Al-Hassan et al., 2011). Jape (2023) revealed that local radio stations play a crucial role in disseminating localized and culturally relevant information. They serve as channels for sharing essential knowledge on health, education, agriculture, and local governance, providing a voice to marginalized communities and facilitating greater community participation.

Mobile phones and mobile phone-based applications, including regular calls and text messages, have great potential in fast-tracking access to agricultural information. Edward et al. (2021) studied the potential of mobile phone-based platforms in improving access to agricultural information for farmers. The study revealed that 77.6% of respondents own smartphones, and 32.7% use internet-based platforms to search for agricultural information. This finding underscores the need to develop internet-based platforms tailored to farmers' local contexts, providing easier access to agricultural information. Ramavhale et al. (2024) found that farmers are using mobile-based platforms to disseminate agricultural information. This signifies that mobile phones play a vital role in disseminating information within the agricultural sector.

Kumar (2023) notes that farmers commonly use various platforms to access agricultural information, including private agricultural solutions helplines, government agriculture officers/extension agents via calls or SMS, private agricultural companies/pesticide dealers through calls or SMS, and government agriculture department helplines. The farmers believe these network technologies are effective in increasing their knowledge and understanding of new agricultural technologies.

Information sharing in the agricultural sector across Africa, particularly among key stakeholders in various value chains—especially those with large numbers, such as farmers—also takes place through in-person meetings. These include farmer-to-farmer interactions, training sessions, field exhibitions, and farmer field days. Gwimile and Yongsheng (2022) observed that the primary source of agricultural information for farmers was in-person meetings with fellow farmers and extension officers. Cherotich and Mireri (2024) also showed that farmers learn about different Integrated Pest Management (IPM) practices through various information channels, including farmer-to-farmer training, field exhibitions, and farmer field days.

Studies reviewed have shown that there are various channels for disseminating information to different stakeholders in the agricultural sector across Africa. These include the use of local radios tailored to the audience's context and mobile phones, such as regular calls, text messages, and WhatsApp, as well as in-person meetings between stakeholders and experts, depending on the type of information being shared. The majority of these studies have focused on farmers and other community groups, including youth. However, there has been limited research targeting marketplace traders, the majority of whom are women (Sperling et al., 2021; Ochieng et al., 2024a) (Table 1).

3 Materials and methods

3.1 Quantitative data: marketplace traders' survey

The study utilized cross-sectional data collected in 2023 from all seven ecological zones in Tanzania, including the Lake, Western, Southern, Southern Highlands, Northern, Eastern, and Central zones. A total of 18 regions were covered; the selection was made based on their significance in the production and trade of common beans, sorghum, and groundnuts (Figure 1). A multi-stage sampling approach

TABLE 1 Comprehensive review of the literature on key methods for sharing information with different stakeholders, including both farmers and marketplace traders.

Title	Author, year	Key strategies	Targeted group
Farmers' use of the mobile phone for accessing agricultural information in Haryana.	Kumar (2023)	Phone calls/short messaging services (SMS), WhatsApp, and YouTube.	Farmers
Utilization of digital tools in extension service delivery amongst extension agents in Akwa Ibom State, Nigeria.	Ifeanyi-Obi and Corbon (2023)	WhatsApp and mobile phone calls	Farmers
WhatsApp for dairy farmers as an effective ICT tool.	Bhatt et al. (2020)	WhatsApp	Dairy farmers
Using radio and interactive ICTs to improve food security among smallholder farmers in Sub-Saharan Africa.	Hudson et al. (2017)	Local radio and mobile phone	Farmers
A study on the role of social media in agriculture marketing using WhatsApp.	Singh et al. (2019)	WhatsApp	Farmers
Potential of mobile-based apps online platforms in fast-tracking access to agriculture information.	Edward et al. (2021)	Mobile phone-based platforms	Farmers
The benefits of social media platforms used in agriculture for information Dissemination.	Ramavhale et al. (2024)	Social media platforms and in-person meetings, i.e., training	Farmers
Influence of social media on agricultural advisory service: an analytical study on the agricultural extension specialists of Uttar Pradesh.	Das (2021)	Social media such as blogs and WhatsApp, accessed through mobile phones	Extension specialists, farmers, and agricultural entrepreneurs
Effectiveness of WhatsApp for sharing agricultural information among farmers of Himachal Pradesh.	Thakur and Chander (2018)	WhatsApp	Farmers
Prospects of Community Radio Broadcast as an Agricultural Extension Service Delivery Tool to Smallholder Farmers in South Africa	Mhlaba and Yusuf (2020)	Local radio	Farmers
Use of community radio to communicate agricultural information to Zimbabwe's peasant farmers.	Nyareza and Dick (2012)	Local radio	Farmers
Role of community radio in promoting rural development: A case study of radio Habari Njema in Mbulu district, Manyara, Tanzania.	Stephen and Kopoka (2019)	Local radio	Farmers
Role of local/community radio in rural development.	Timalsina and Pradhan (2019)	Local radio	Rural communities
Use of the WhatsApp application in fruit marketing communication: Traders' Experience.	Akhmadi et al. (2021)	WhatsApp	Marketplace traders
A new paradigm shift in how WhatsApp empowers small businesses to develop customer relationships, and it becomes an integral part of business	Naneetha (2018)	WhatsApp	Small business owners and customers
Community radios promote local development across Africa.	UNESCO (2023)	Local radio	Community members/ villagers
Assessing the impact of community radio on disseminating information and fostering youth development in Zanzibar.	Jape (2023)	Local radio	Youth
The Role of Community Radio in Livelihood Improvement: The Case of Simli Radio.	Al-Hassan et al. (2011)	Local radio	Community members, including the Small and Medium Enterprises (SMEs)
Agricultural information gathering and use among smallholder sugarcane farmers during the COVID-19 pandemic in Tanzania.	Gwimile and Yongsheng (2022)	In-person meetings with extension officers, fellow farmers, and the use of local radio	Farmers
Agricultural information sources, channels, and strategies for sharing agricultural research findings among farmers in Iringa district in Tanzania.	Mubofu and Malekani (2020)	Local radio, church leaders, seminars, newspapers, brochures, and fliers	Farmers
Assessment of information dissemination channels for the adoption of integrated pest management among large-scale farmers in Uasin Gishu, Kenya.	Cherotich and Mireri (2024)	Farmer-to-farmer training, field exhibitions, farmer field days, television, local radio, and extension officers	Farmers

was employed, beginning with the purposive selection of key regions and markets based on the production and trade patterns of the three targeted crops. Then, 5 to 10 traders per crop from each market were randomly selected. The final sample comprised 657 marketplace traders (372 women and 285 men) to study the characteristics of marketplace traders, approaches to receiving information about newly

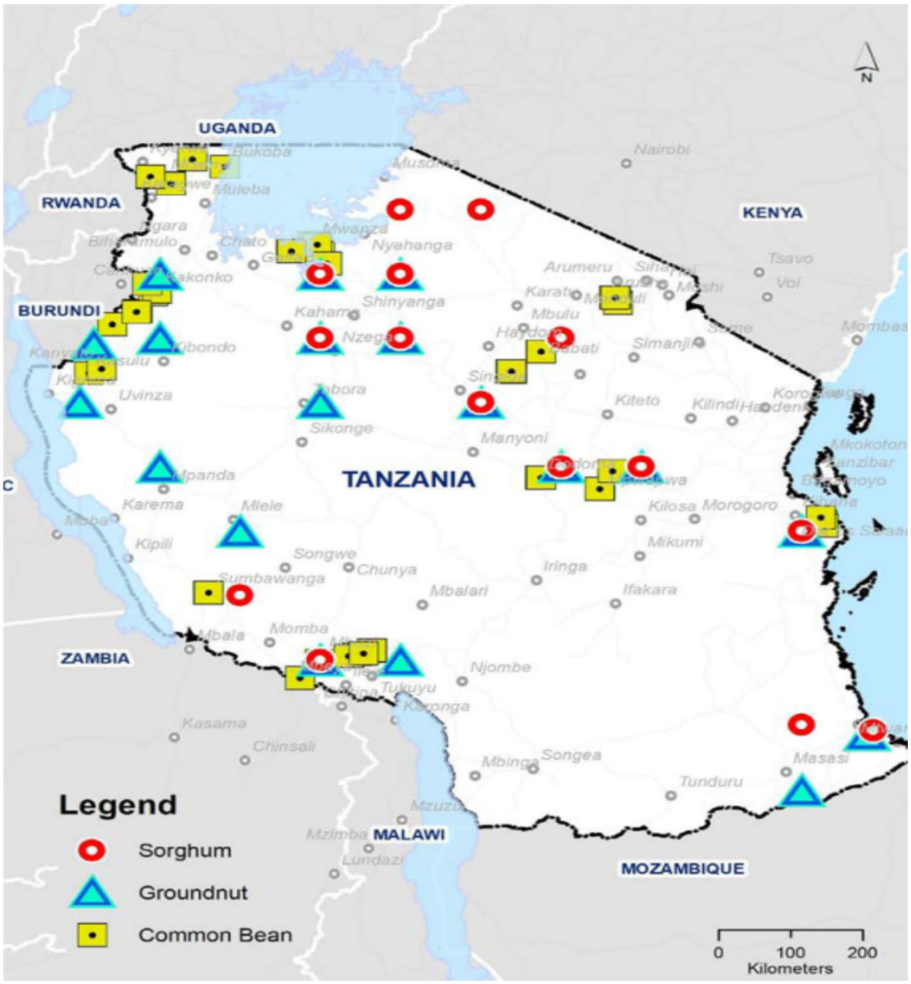

FIGURE 1
Surveyed regions.

released climate-resilient varieties by marketplace traders, and socio-economic characteristics influencing the traders' preferences regarding the selection of the approaches to be adopted.

3.2 Qualitative data: marketplace traders' complementary data

To complement the quantitative survey data, qualitative data were collected specifically to examine marketplace traders' preferred methods for receiving information on newly released climate-resilient varieties. Nine markets were selected along major commodity corridors for common beans, sorghum, and groundnuts across different regions of the country: Northern, Coastal, Southern, Southern Highlands, Central, and Lake Zone. The selection considered three types of market segments: production hubs, distribution hubs, and consumption hubs, ensuring the collection of comprehensive and diverse data, as detailed in Ochieng et al. (2024a, 2024b). These nine markets are located in eight regions: Arusha, Kigoma, Shinyanga, Dodoma, Songwe, Mbeya, Dar es Salaam, and Mtwara. Each market exhibited at least one, two, or all three of the characteristics of the market segments. The selected markets included Kilombero and Arusha Central Market in the Arusha region, Sofya Market in the Kasulu-Kigoma region, Namanga Market in the Kahama-Shinyanga region, Dodoma Central Market in the Dodoma region, Tunduma Central Market in the Songwe region, Mbalizi Market in the Mbeya region, Tandika Market in the Dar es Salaam region, and Kilimahewa Market in the Nanyumbu-Mtwara region.

A qualitative data collection approach was employed, and data were collected through Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) with marketplace traders in the nine sampled markets. FGDs were conducted with marketplace traders of specific crops, with each crop being interviewed separately in groups of 3 to 10 traders. KIIs were conducted with market leaders who have extensive knowledge of the targeted crop businesses in their markets, as well as with crop leaders for the markets.

Overall, 55 interviews were conducted, consisting of 28 FGDs and 27 KIIs. A total of 180 marketplace traders were engaged in FGDs and interviews, of whom 75 (42%) were male marketplace traders and 105 (58%) were female marketplace traders. Among them, 73 (41%) were common bean marketplace traders, 58 (32%) were groundnut marketplace traders, and 49 (27%) were sorghum marketplace traders. The qualitative data collected by the team are documented in notes for each interview, and each interview session was recorded using a recorder.

3.3 Data analysis

3.3.1 Descriptive statistics

Qualitative data collected were reviewed and coded manually in Microsoft Excel. A lead researcher conducted the initial coding, grouping responses into categories based on recurring themes and patterns, such as awareness of new climate-resilient varieties, motivation to promote these newly released varieties, marketplace traders' willingness to accelerate their adoption, and preferred approaches among marketplace traders. A secondary researcher reviewed the coded data to ensure consistency and reduce bias. To support credibility and trustworthiness, codenames were developed to guide interpretation, and regular peer debriefing sessions were held to validate the emerging themes, thereby enhancing the reliability and analytical depth of the qualitative findings.

Qualitative data were analyzed using a content analysis approach. The ethnographic method was central to both data collection and analysis in this study, involving direct engagement with participants through observations during interviews, recording of interview notes, listening, transcription, documentation, interpretation, and visualization. Descriptive statistics were used to analyze quantitative data on the socio-economic characteristics of marketplace traders and their methods of receiving information about newly released climate-resilient varieties. STATA software (version 18) was used for analysis. Chi-squared tests (χ^2) were applied to assess statistically significant associations between categorical variables, such as marketplace traders' gender and other socio-economic characteristics.

3.3.2 Factors influencing marketplace traders' preference for different communication approaches

We used a multivariate probit (MVP) model to estimate factors influencing the likelihood of marketplace traders preferring different communication approaches for accessing information about newly released climate-resilient varieties. The MVP accounts for potential correlations between the unobserved factors influencing these decisions, which may arise from complementarities (positive correlations) or substitutability (negative correlations) among channels. This method is particularly suited for modeling multiple binary outcomes that may be interdependent. In our case, a marketplace trader may prefer to receive varietal information via more than one approach or use all the communication approaches (Equation 1).

Following the studies by Lin et al. (2005), the MVP used in this study is characterized by a set of n binary dependent variables yi (with observation subscripts suppressed), such that

$$\begin{aligned} y_i &= 1 \text{ if } x'\beta_i + \varepsilon_i > 0, \backslash \\ &= 0 \text{ if } x'\beta_i + \varepsilon_i \leq 0, i = 1, 2, \ldots\ldots\ldots, n \end{aligned} \quad (1)$$

Where x is a vector of explanatory variables presented in Table 2, $\beta_1, \beta_2 \ldots\ldots\ldots\beta_n$ are conformable parameter vectors, and random error terms $\varepsilon_1, \varepsilon_2, \ldots \varepsilon_n$ are distributed as a multivariate normal distribution with zero means. Marketplace traders' location may also influence the preference in communication approaches and reflect different conditions in urban and rural markets. To address this, we included the marketplace traders' location in the model.

The marginal effects of the explanatory variables on the likelihood of preferring each communication approach were calculated. The marginal effect represents the percentage change in the probability of adoption associated with a one-unit increase in the explanatory variable from its mean value. For dummy variables, the marginal effect measures the change in probability when the variable shifts from 0 to 1. Marginal effects are presented because they are easier to interpret and indicate the strength and direction of the relationship between marketplace traders' characteristics and the use of different communication approaches.

4 Results

4.1 Socio-economic characteristics of marketplace traders

The survey found that out of 657 marketplace traders interviewed, 57% were female, with the majority of marketplace traders falling within the 30- to 65-year age group. No statistically significant difference was found in age distribution between men and women. More female marketplace traders lacked formal education compared to men, while male marketplace traders were more likely to have attained formal education. The statistical test showed a significant gender difference in education, with male marketplace traders having higher educational attainment than female marketplace traders. Moreover, the location of marketplace traders differed significantly by gender, with female marketplace traders being more localized in rural markets, while male marketplace traders were more likely to operate across broader areas, particularly in urban markets. Significant gender gaps exist in access to smartphones, radio, and television, with male marketplace traders having more access than female marketplace traders. Access to featured mobile phones is similar across genders, with no statistically significant difference (Table 2).

4.2 Approaches to receiving information about newly released climate-resilient varieties from quantitative data

Marketplace traders are a type of value chain actor who have been largely uninvolved in research on crop varieties, but they are one of the major avenues to reach farmers to grow improved, climate-resilient varieties, and consumers to consume grains of improved varieties with higher nutritional value. Marketplace traders work directly with last-mile consumers and are connected to farmers, especially in rural markets, and they are knowledgeable about what consumer demands and needs are. They also act as sources of planting material for farmers living in rural areas during the planting season (Ochieng et al., 2024a; Sperling et al., 2021). Therefore, before engaging them in promoting these new and improved climate-resilient varieties of common beans, sorghum, and groundnuts, it is crucial to use approaches that are effective and efficient for them to receive information.

The analysis of the marketplace traders' survey data revealed that traders use a variety of approaches to access information about newly released climate-resilient varieties. These approaches include in-person meetings, where marketplace traders receive information face-to-face at the market, as well as phone calls, SMS/text messages, and WhatsApp. These channels play an important role in facilitating the flow of information among marketplace traders and between marketplace traders and other actors in the value chain (Figure 2).

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TABLE 2 Socio-economic characteristics of marketplace traders.

Variables	Definition	Category	Women (n = 372)	Men (n = 285)	t/chi square (*p*-value) (a ≠ b)	Total (n = 657)
Gender	0 = women, 1 = men	–	372	285		657
Age group	Age in years	15–29	17.74	17.19	0.652	17.50
		30–45	47.04	50.53		48.55
		46–65	31.72	30.18		31.05
		66 and above	3.49	2.11		2.89
Education	0 = No formal 1 = primary, 2 = O-level, 3 = High school 4 = Tertiary	No Formal	8.06	3.16	0.000	5.94
		Primary	67.20	63.51		65.60
		o-level	21.51	23.51		22.37
		High school	2.15	2.81		2.44
		Tertiary	1.08	7.02		3.65
Location of farmers	0 = within district 1 = Outside district	Within district	65.24	50.68	0.025	58.86
		Outside district	34.76	49.31		41.14
Support to farmers (In terms of credit offer)	1 = yes, 0 = No	No	77.15	77.54	0.905	77.32
		Yes	22.85	22.46		22.68
Market type	0 = Urban 1 = Rural	Urban	57.38	77.94	0.000	66.41
		Rural	42.62	22.06		33.59
Crop type	1 = Beans 2 = sorghum 3 = Groundnuts	Beans	41.23	33.81	0.016	37.97
		Sorghum	30.92	27.76		29.53
		Groundnuts	27.86	38.43		32.50
Smartphone	0 = Do not own 1 = Own smartphone	Not owning	54.04	46.62	0.062	50.78
		Owning	45.96	53.38		49.22
Feature mobile phone	0 = Do not own 1 = Own feature phone	Not owning	22.84	19.57	0.317	21.41
		Owning	77.16	80.43		78.59
Radio	1 = No Access 2 = Having access	No Access	18.94	10.68	0.004	15.31
		Having access	81.06	89.32		84.69
Television	1 = No Access 2 = Having access	No Access	29.53	19.57	0.004	25.16
		Having access	70.47	80.43		74.84

4.3 Approaches to receiving information about newly released climate-resilient varieties from qualitative data

From the complementary data, which were aimed at learning the preferred approaches by marketplace traders to receive information about the newly released climate-resilient varieties, various approaches were suggested, including in-person meetings, phone calls, SMS/text messages, and WhatsApp, the same ways they were identified from the marketplace traders' survey. However, at this stage, other approaches, such as the use of local radios and television, emerged. The table below shows the specific approaches preferred by marketplace traders of common beans, sorghum, and groundnuts (Table 3).

The findings were further disaggregated by gender and market type (Table 3). Marketplace traders in urban markets, such as Dar es Salaam, Dodoma, and Arusha, preferred WhatsApp. Marketplace traders in rural areas, i.e., those located in production hubs, preferred the use of local radios for receiving information about the climate-resilient varieties. In-person meetings with marketplace traders, as well as the use of text messages and phone calls, are the preferred approaches in all types of markets, including both urban and rural markets.

On the other hand, female marketplace traders preferred the SMS approach, followed by in-person meetings and local radio. Many female marketplace traders preferred text/SMS because the messages can be saved and referred to at any time. In-person meetings were favored for providing direct opportunities to ask questions and receive clarifications. Additionally, female marketplace traders were more dominant in the rural markets visited. In contrast, men marketplace traders, who dominated in urban markets, found that WhatsApp was the most preferred approach, followed by in-person meetings, local radio, and phone calls.

4.4 Socio-economic factors influencing marketplace traders' preference for information access approaches

The estimates of socio-economic characteristics influencing the likelihood of marketplace traders to use specific approaches for

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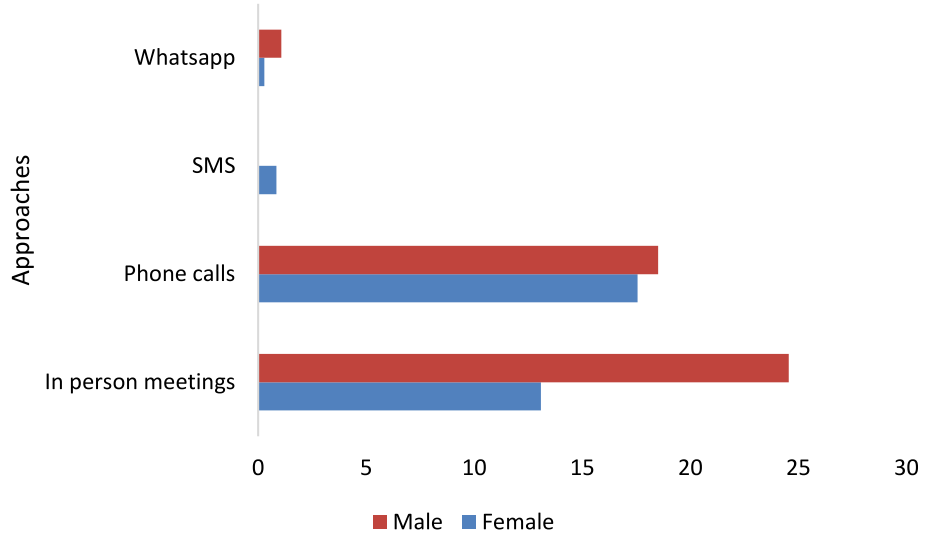

FIGURE 2
Approaches to receiving information by marketplace traders.

TABLE 3 Approaches to receiving information about newly released climate-resilient varieties from qualitative data.

Approaches	Overall %	Rank	Categorical rank			
			Rural	Urban	Men	Women
In-person meetings	19	1	2	2	2	2
WhatsApp	18	2	4	1	1	4
Local radios	18	2	1	3	3	3
Phone call	18	2	3	3	3	2
SMS/text	16	3	3	3	4	1
Television	6	4	5	4	5	7
Poster/leaflets in the markets (Swahili).	3	5	7	5	5	5
Open fairs in the market with cooking sessions	1	6	6	6	5	6

For the preferred approaches, multiple responses were applied. Rank: 1 = most preferred.

receiving information about newly released climate-resilient varieties of common beans, sorghum, and groundnuts are presented in Table 4. The results show that male marketplace traders were more likely than female traders to prefer in-person meetings over phone calls and SMS. Female marketplace traders often have greater household responsibilities, which limit both their time in the marketplace and their ability to participate in extended in-person meetings. Consequently, they rely more on remote communication channels such as SMS or phone calls, which are less time-demanding.

Education was also shown to have a positive association with the use of approaches for receiving information on the newly released climate-resilient varieties by marketplace traders. Results showed that marketplace traders with relatively higher education levels are more likely to use in-person meetings rather than phone calls and SMS than marketplace traders with relatively low education levels. Educated marketplace traders are often more confident in engaging in face-to-face interactions, which are important for building trust and exchanging information with experts, extension officers, and researchers. In-person meetings tend to offer richer, more interactive, and contextualized information compared to SMS or phone calls. As a result, educated marketplace traders may prefer this approach, as they value detailed explanations, live demonstrations, and opportunities for real-time questions and answers. However, it is important to consider other approaches, as less-educated marketplace traders tend to form a large group, as evidenced by Mbegalo et al. (2024).

The ownership of phones, especially smartphones, was also examined in relation to the likelihood of using different approaches for receiving information about newly released climate-resilient varieties. The results showed that marketplace traders who own smartphones are more likely to prefer using SMS-based approaches, including text messages and WhatsApp, compared to those who own feature phones. This can be explained by the fact that smartphones offer greater functionality and access to internet-based applications like WhatsApp, enabling traders to receive multimedia content, join information-sharing groups, and engage in two-way communication. In contrast, feature phones have limited capabilities, restricting users to basic SMS or voice calls.

The marketplace trader's location was positively associated with the preferred approaches for receiving information about newly

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TABLE 4 Socio-economic characteristics influencing marketplace traders' preference for information access approaches.

Variables	In-person meeting	Phone calls	SMS (Text message and WhatsApp)
Sex (1 = male)	0.333***	0.0402	−0.0249
	(−0.115)	(−0.109)	(−0.165)
Age of the trader			
30–45	−0.11	0.181	0.286
	(−0.153)	(−0.149)	(−0.235)
46–65	−0.0174	0.0884	0.222
	(−0.17)	(−0.165)	(−0.263)
66 and above	−0.185	0.458	0.486
	(−0.389)	(−0.334)	(−0.516)
Education (0 = Primary school/no school, 1 = o-level and above)	0.221*	0.154	0.242
	(−0.131)	(−0.125)	(−0.18)
Traders Location (0 = within district, 1 = otherwise)	−0.199	−0.0678	0.121
	(−0.125)	(−0.118)	(−0.189)
Support to farmers Yes (Seed credit) (1 = yes, 0 = No)	0.0873	0.324***	0.0557
	(−0.132)	(−0.125)	(−0.192)
Digital literacy score	−0.141	−0.0063	0.15
	(−0.156)	(−0.149)	(−0.205)
Owns smartphone (1 = owns;0 = otherwise)	0.175	0.166	0.341*
	(−0.132)	(−0.125)	(−0.191)
Own feature phone (1 = owns;0 = otherwise)	−0.255*	−0.193	−0.0711
	(−0.141)	(−0.135)	(−0.195)
Market type (1 = rural; 0 urban)	0.294**	0.433***	−0.0762
	(−0.132)	(−0.126)	(−0.188)
Constant	−0.791***	−0.904***	−2.053***
	(−0.221)	(−0.215)	(−0.339)
atrho31	0.304***	−0.270***	0.352***
	(−0.0695)	(−0.102)	(−0.0964)
Observations	640	640	640

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Figures in brackets are standard errors.

released climate-resilient varieties. The results showed that marketplace traders located in rural markets were more likely to rely on phone calls and in-person meetings. This may be due to limited access to reliable Internet and digital platforms in rural areas, which restricts the use of online channels. Voice calls remain the most practical and trusted method, as discussed by Kinyashi et al. (2022). Among the surveyed smallholder farmers, 97.2% owned a mobile phone capable of making calls and sending SMS, while only 18.8% had Internet-enabled phones. In addition, rural traders often operate in closely knit communities where information is traditionally exchanged through personal networks, local meetings, and direct contact, further reinforcing the preference for these approaches.

Marketplace traders who provide seed credit support to farmers are more likely to prefer phone calls for receiving information about newly released climate-resilient varieties. The relationship is not statistically significant for in-person meetings or SMS/WhatsApp, indicating that the effect of seed credit provision is specific to phone communication. This may reflect the need for frequent and direct follow-up with farmers receiving credit, for which phone calls provide a timely and personalized medium. Seed credit arrangements also rely on trust, and phone calls allow for more personal, two-way communication than SMS or WhatsApp, helping maintain strong marketplace trader–farmer relationships. Based on this experience, marketplace traders may also prefer using phone calls to receive information about climate-resilient varieties.

4.5 Women's awareness of newly released climate-resilient varieties and their willingness to engage in their promotion

It was largely found that marketplace traders were not aware of the existence of new climate-resilient varieties of common beans, sorghum, and groundnuts released by the Tanzania Agricultural Research

Institute (TARI). The results showed that 85% of marketplace traders revealed a lack of awareness about these newly released climate-resilient varieties, with only 15% being aware of them. Moreover, 96% of the overall marketplace traders confirmed their willingness to participate in promoting the climate-resilient varieties among farmers, as they see value in selling grains of improved varieties (Figure 3). These results are consistent with those of Ochieng et al. (2024a), who found that 92 and 100% of marketplace traders interviewed from urban and rural markets, respectively, were willing to participate in promoting the acceleration of newly released climate-resilient varieties.

Findings show that marketplace traders are motivated to promote newly released climate-resilient varieties among farmers by providing information about the quality and benefits of these varieties and highlighting similarities between old and new ones, as detailed by Mwakatwila et al. (2024). Additionally, the assurance that these new varieties meet customer preferences and demand, along with features such as climate resilience, nutritional value, taste, cooking time, and others, affects their motivation. Factors such as reasonable pricing, customer awareness, availability, consistent supply from sourced locations, and the ability of these varieties to resist pests during storage were also highlighted. It was noted that many existing sorghum varieties on the market are heavily affected by pests during storage, and their use for food is relatively low in regions such as Mbeya and Mtwara due to a lack of nutritional knowledge. Moreover, the similarity in appearance between new and old varieties could easily encourage customer acceptance, making marketplace traders more inclined to stock them.

5 Discussion

Marketplace traders are critical yet often overlooked actors in the value chain of agricultural innovation systems. While they have traditionally been excluded from the research and development processes surrounding crop varieties, they are key beneficiaries of improved, climate-resilient varieties (Nchanji and Lutomia, 2020; Mabaya et al., 2021). Their position at the interface between farmers and last-mile consumers, especially in rural markets, provides them with unique insights into consumer demand and positions them as informal seed distributors, often serving as a key source of planting material during planting seasons (Gundu et al., 2022). Given this strategic role, it is essential to explore effective and efficient strategies for disseminating information to marketplace traders about newly released climate-resilient varieties promoted by initiatives such as the Accelerate project.

Effective communication approaches for disseminating information about newly released climate-resilient varieties are essential for engaging marketplace traders. The marketplace traders interviewed in the traders' study emphasized the need for user-friendly approaches that align with their busy schedules and market-centered activities. Using in-person meetings organized with experts and market leaders was perceived as both accessible and trustworthy, given the established relationships and influence these leaders hold within the trader community (Nchanji and Lutomia, 2020). SMS/text messaging was also preferred due to its convenience; messages can be saved and read at a suitable time, offering flexibility for marketplace traders who may not be able to answer calls during work hours (Munyua et al., 2020). While phone calls are recognized as a viable method, the nature of marketplace operations often limits the ability to provide timely responses. Interestingly, WhatsApp groups are particularly favored among urban marketplace traders in Arusha, Dodoma, and Dar es Salaam. These groups allow for quick information sharing and peer-to-peer reinforcement, whereby if a message is missed by one trader, others can relay the information (Kansiime et al., 2021). Despite the noted low adoption of WhatsApp platforms among many marketplace traders, especially in rural areas, there is recognition of their potential, informed by their use in non-business contexts, such as religious groups. These findings underscore the importance of tailoring communication approaches to both contextual and demographic factors, as similarly observed by Gundu et al. (2022), who highlighted the effectiveness of multi-channel strategies in reaching diverse value chain actors.

This study, which complements the previously discussed approaches from the marketplace traders' survey, also qualitatively

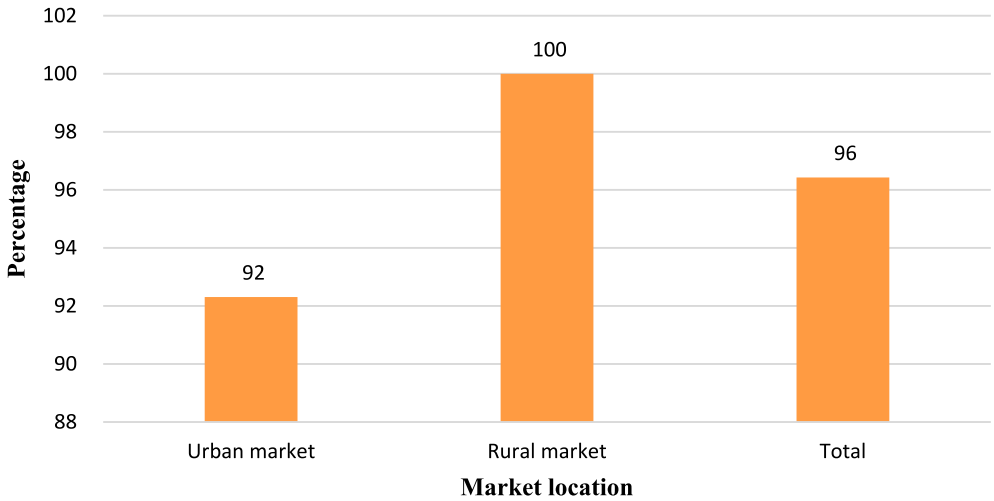

FIGURE 3
Traders' willingness to engage in promoting and accelerating newly released climate-resilient varieties.

assesses the approaches that are preferred by marketplace traders, who are 80% women (Ochieng et al., 2024a), in engaging them to accelerate the newly released climate-resilient varieties of common beans, sorghum, and groundnuts in Tanzania. Results show that in-person meetings organized by researchers, development partners, and market leaders in markets foster trust and provide marketplace traders with tangible insights into product quality (Kansiime et al., 2021). Using bulk SMS/text messages to deliver information and engage marketplace traders in accelerating the adoption of newly released varieties, followed by the use of digital platforms such as WhatsApp and WhatsApp groups, mobile phone calls, and local radios, was the preferred approach in engaging marketplace traders to scale up the use of improved varieties and increase crop productivity in rural areas. This aligns with Munyua et al. (2020), who emphasize the effectiveness of multi-channel communication in reaching diverse agricultural stakeholders.

On the other hand, preferences differ depending on the location of the market and the gender of the marketplace trader. For markets in urban areas such as Dar es Salaam, Dodoma, and Arusha, digital platforms such as WhatsApp are preferred because as many as 56% of marketplace traders own smartphones (Steinke et al., 2024) and have reliable internet access, as well as direct in-person meetings and phone calls, as 96% of marketplace traders own a mobile phone (Steinke et al., 2024). These findings align with research by Munyua et al. (2020), which highlighted the growing role of digital platforms such as WhatsApp in urban agricultural markets for information exchange and coordination. Several studies have examined the benefits of using WhatsApp platforms in business, including the one by Akhmadi et al. (2021), which revealed a strong and positive correlation between benefit factors and the use of WhatsApp. Naneetha (2018) indicated that WhatsApp is becoming a tool that empowers many small businesses and drives a new paradigm shift. Besides serving as a communication platform, WhatsApp facilitates customer relationships and support, making it an essential part of the business process. A total of 9% of traders employ WhatsApp specifically to find customers, and 43% of traders use WhatsApp in their business at least monthly (Steinke et al., 2024). This also highlights the need for multistakeholder platforms (MSPs), particularly those led by traders and actively involving marketplace traders and other value chain actors. Such platforms are increasingly recognized by large traders/off-takers and processors as valuable mechanisms for coordination, information sharing, and strengthening market linkages (Mwakatwila et al., 2024).

For markets located in rural areas such as Nanyumbu district in Mtwara Region and Kasulu district in Kigoma Region, they mainly prefer using local radios, as it is viewed as a cost-effective and accessible approach, particularly in areas with limited internet connectivity or where marketplace traders spend most of their time in the marketplace (Nchanji and Lutomia, 2020). This is followed by in-person meetings, SMS/text messages, and phone calls. Unlike markets located in urban areas, these rural markets tend to prefer using local radios. This finding is also aligned with several studies that examined the role of local radio in livelihood improvement and showed that local radios promote small and medium enterprise (SME) development by creating market opportunities (UNESCO, 2023; Al-Hassan et al., 2011). Jape (2023) outlined that local radio stations play a significant role in disseminating localized and culturally relevant information. Hence, local radios are an efficient tool for educating and informing people in rural areas.

Gender differences also shape communication approach preferences. Unlike their male counterparts, female marketplace traders prefer receiving information about climate-resilient varieties through text messages, phone calls, in-person meetings, and local radio. Text messages provide a quick and accessible way to receive updates, which can be reviewed later, while phone calls offer real-time clarification and personalized communication. In-person meetings help build trust and offer hands-on learning, while local radio reaches even the most remote areas, delivering relevant information in a format that resonates with women. This reflects broader gendered patterns in technology access and use in agricultural value chains (Mabaya et al., 2021). This is also supported by other studies. According to Aker (2011), the use of mobile phones (SMS and phone calls) to disseminate agricultural information, especially among female farmers and traders in Africa, has increased. Similarly, the World Bank (2017) states that mobile phones and local radio stations play a vital role in sharing agricultural information, particularly with female farmers. Additionally, Mtega and Msungu (2013) emphasize that SMS, mobile calls, and local radio are key channels for delivering agricultural information to women in the marketplace and to farmers. These findings align with the observed preferences and highlight the critical role of technology and localized communication in transforming agricultural practices.

The findings also evidenced that socio-economic characteristics may influence the preferences of marketplace traders in the approaches they use to receive information on climate-resilient varieties. The gender differences between female and male marketplace traders imply that female traders face limitations, such as time constraints due to household responsibilities, which reduce their participation in time-intensive approaches like in-person meetings. On the same note, there is a positive association between education and the use of in-person meetings, which aligns with the fact that educated individuals are more confident in formal interactions and are better positioned to engage in complex knowledge exchange processes. Smartphone ownership increases the likelihood of using digital messaging platforms, such as WhatsApp, which can support multimedia information sharing and group engagement, as well as text messages. This emphasizes the growing relevance of digital tools in agricultural extension. Moreover, the influence of location reinforces the urban–rural gap in information access. Urban marketplace traders benefit from better infrastructure, stronger networks, and more frequent interactions with information providers. Together, these insights highlight the need for tailored communication approaches that cater to the distinct needs and constraints of diverse marketplace trader groups, thereby ensuring equitable access to information on climate-resilient varieties.

The study also revealed limited awareness among marketplace traders regarding newly released climate-resilient varieties of common beans, sorghum, and groundnuts, with 85% of respondents being unaware of these new varieties. Encouragingly, 96% of marketplace traders expressed a willingness to engage in promoting climate-resilient varieties, recognizing potential benefits such as improved nutrition, alignment with customer preferences, and enhanced market opportunities. These findings align with the existing literature, which underscores the role of awareness and access to information in influencing the adoption and dissemination of agricultural innovations (Spielman et al., 2009). Furthermore, studies emphasize

the importance of engaging non-traditional value chain actors, such as marketplace traders, in promoting new agricultural technologies, particularly when these actors serve as a vital link between farmers and consumers (Nigusie et al., 2021). Given that marketplace traders often act as both buyers and informal seed suppliers to farmers, their involvement can significantly contribute to accelerating the uptake of climate-resilient varieties, especially in informal seed systems that dominate in many developing countries (Almekinders et al., 2019).

The marketplace traders interviewed identified several motivating factors that can influence their decision to promote and accelerate the release of newly climate-resilient varieties of common beans, sorghum, and groundnuts. A key motivator is access to clear and reliable information distinguishing the new varieties from older ones, particularly in terms of their quality, benefits, and market potential. Specific traits such as climate resilience, nutritional value, taste, reduced cooking time, and resistance to pests during storage are viewed as particularly valuable. This is consistent with findings from Kansiime et al. (2021), who highlight that the perceived benefits of improved seed varieties strongly affect trader and farmer adoption decisions. Additionally, marketplace traders emphasize the importance of ensuring these varieties meet customer preferences, are affordably priced, are consistently available, and are easy to source. The issue of post-harvest losses, especially with sorghum varieties prone to insect damage, further reinforces their interest in insect pest-resistant varieties, a factor also noted by Munyua et al. (2020).

Notably, the physical similarity of new varieties to old ones is identified as a practical advantage, making it easier for marketplace traders to introduce them to customers. However, marketplace traders also stressed the need for accurate information on variety characteristics, sourcing channels, and yield potential. This need is particularly prominent among those who also engage in farming, especially in rural areas. As Nchanji and Lutomia (2020) suggest, improving information flow to value chain actors, such as traders, can significantly enhance the adoption and dissemination of improved varieties. These findings underscore the importance of tailored communication approaches and the inclusion of marketplace traders in early dissemination efforts, as their role in the grain value chain is critical to reaching last-mile consumers and influencing market uptake (Mabaya et al., 2021; Gundu et al., 2022).

Moreover, this study specifically focused on identifying the preferred communication approaches used by female marketplace traders to share information about newly released climate-resilient varieties with them. Aiming to shift marketplace traders' demand towards grains derived from improved climate-resilient varieties, hence incentivizing farmers to adopt and cultivate these varieties at scale. However, this study did not go as far as to evaluate the actual impact of sharing information with marketplace traders on varietal adoption and turnover. This presents an opportunity for further research, particularly on the impact of sharing information among marketplace traders on the varietal adoption and turnover for climate-resilient varieties.

6 Conclusion

Efforts to scale up improved varieties have often fallen short, with many smallholders not adopting them. As a result, farmers continue recycling old seeds or planting grain meant for consumption, leading to low yields and unmet supply and consumer demand. A key bottleneck is the lack of engagement with marketplace traders, who prefer older varieties due to limited awareness and knowledge of new, high-yielding, climate-resilient varieties. This study examined the preferred approaches for raising awareness of climate-resilient varieties among marketplace traders, aiming to shift marketplace traders' demand towards grains derived from improved, climate-resilient varieties, thereby incentivizing farmers to adopt and cultivate these varieties at scale.

Over 96% of marketplace traders expressed a willingness to promote climate-resilient varieties, recognizing benefits such as improved nutrition, increased customer demand, and assured sustainable markets and profits. Key motivators include access to information on variety quality, the benefits of new varieties over older types, and clear marketplace benefits for traders and businesses. Marketplace traders prefer to receive information and engage through in-person meetings, where researchers can visit them with samples of the respective climate-resilient varieties. Other recommended approaches include making phone calls, using local radio stations, and utilizing digital platforms such as WhatsApp. Marketplace traders located in urban areas, such as Dar es Salaam, Dodoma, and Arusha, preferred WhatsApp, while those in rural areas preferred using local radios to receive information about climate-resilient varieties. In-person meetings, the use of text messages and phone calls are the most preferred approaches across all types of markets.

On the other hand, female marketplace traders preferred SMS, followed by in-person meetings and local radio. SMS is preferred because the messages can be saved and referred to at any time. In-person meetings provide direct opportunities to ask questions and receive clarifications on the spot. Hence, development practitioners should consider women's preferences when sharing information with them to ensure effective and efficient reach to female marketplace traders. In contrast, male marketplace traders, who dominate in urban markets, preferred WhatsApp, in-person meetings, local radio, and phone calls in that order. The variation between female and male marketplace traders can be attributed to their differences in roles and responsibilities, with women often balancing motherhood and wifehood alongside their business activities, leading them to prefer communication methods that provide flexibility and convenience, such as SMS, phone calls, in-person meetings, and local radio.

Scaling organizations and practitioners, in collaboration with research institutes such as TARI and CGIAR and NGOs, can partner with local radio stations to broadcast programs on newly released climate-resilient varieties, specifically reaching female farmers who listen to local radio regularly. Involving market leaders will help ensure marketplace traders are informed and engaged. Complementary training in business management, seed handling, agronomy, and variety traits will further support the widespread adoption and scaling of these improved varieties.

WhatsApp platforms are becoming increasingly popular among actors in the crop value chain. Therefore, establishing a trader-led Multi-Stakeholder Platform (MSP) driven by market leaders and involving researchers, marketplace traders, large off-takers, financial institutions, and institutional buyers can effectively raise awareness of climate-resilient varieties, stimulate demand and supply of improved grains, and strengthen links between farmers and quality seed suppliers.

Finally, a single approach is not a one-size-fits-all solution and may be effective in some contexts but not in others. Therefore, prioritizing a set of effective approaches that women prefer for sharing information about climate-resilient varieties would have intended adoption impacts.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Alliance of Bioversity International & CIAT. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

AM: Conceptualization, Data curation, Formal analysis, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. JO: Conceptualization, Data curation, Funding acquisition, Methodology, Resources, Supervision, Writing – review & editing. EC: Conceptualization, Data curation, Methodology, Writing – review & editing. JK: Conceptualization, Data curation, Methodology, Writing – review & editing. DM: Conceptualization, Data curation, Methodology, Writing – review & editing. AN: Conceptualization, Data curation, Methodology, Writing – review & editing. EK: Conceptualization, Data curation, Methodology, Writing – original draft, Writing – review & editing. AB: Conceptualization, Data curation, Methodology, Writing – review & editing. AK: Conceptualization, Data curation, Methodology, Writing – review & editing. SM: Conceptualization, Data curation, Methodology, Writing – review & editing. JM: Conceptualization, Data curation, Methodology, Writing – review & editing. RK: Conceptualization, Data curation, Methodology, Writing – review & editing. JR: Conceptualization, Data curation, Funding acquisition, Methodology, Project administration, Resources, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2025.1638748/full#supplementary-material

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