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EDITED BY
Vivian Polar,
International Potato Center, Peru

REVIEWED BY
Hom N. Gartaula,
International Rice Research Institute, India
Sarah Lubega Mayanja,
International Potato Centre, Uganda

*CORRESPONDENCE
Scovia Adikini
adikiniscovia@gmail.com

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Farmer-preferred traits and variety choices for finger millet in Uganda

Sophia Hamba[1], Faizo Kasule[2], Ibrahim Mayanja[1], Moses Biruma[1], Hedwig Natabirwa[3], Losira Nasirumbi Sanya[4], Deborah Rubin[5], Martina Occelli[6] and Scovia Adikini[1]*

[1]National Semi-Arid Resources Research Institute (NaSARRI), National Agricultural Research Organization, Soroti, Uganda, [2]Interdepartmental Genetics and Genomics (IGG), Iowa State University, Ames, IA, United States, [3]Food Biosciences and Agribusiness Center, National Agricultural Research Laboratories (NARL), National Agricultural Research Organization, Kampala, Uganda, [4]School of Agricultural Sciences, College of Agricultural and Environmental Sciences, Makerere University, Kampala, Uganda, [5]Cultural Practice, LLC, Bethesda, MD, United States, [6]Cornell University, Ithaca, NY, United States

Finger millet is a climate-resilient crop providing food and nutrition security and income In Uganda. However, the current productivity of finger millet in farmers' fields is low and among other factors, this is due to the poor adoption of improved varieties. With this study we aim to identify and profile varietal traits preferred by finger millet farmers and consumers in Uganda. We specifically focus on how these traits vary among women and men in the Ugandan finger millet value chain. We collect data using semi-structured questionnaires among 170 households growing millet in Bushenyi, Lira, and Nwoya districts, and we triangulate questionnaires replies with qualitative information from 11 focus group discussions and 3 key informant interviews. Using descriptive statistics and probit regression models, we find that the majority of the farmers (97%) prefer growing landrace varieties of finger millet compared to only 3% growing improved varieties. The most preferred varieties were Kaguma in Bushenyi, Ajuko Manyige in Nwoya, Kal Atar, and Okello Chiba in Lira. Farmers' choice of variety depends on a combination of traits including agronomic, marketing, and consumption traits. Gender, marital status, education levels, and occupation are the major socio-demographic factors that influence specific preferences related to finger millet variety. This study lays a foundation for designing a gender-responsive finger millet product profile to guide the development and release of new varieties by the finger millet crop improvement program.

KEYWORDS
finger millet, gender dynamics, socio-demographic factors, variety preference, Uganda

1 Introduction

Finger millet is a dominant cereals crop grown in Uganda, both in sub-humid and semi-arid regions due to its ability to grow and perform well even in harsh environments (Wanyera, 2005; Owere et al., 2015; Adikini et al., 2021). It is the third most important cereal after sorghum and maize in terms of area under production covering a total land area of 437,000 hectares (UBOS, 2022). It is grown across the whole country, majorly in the eastern, northern, and western regions of Uganda (UBOS, 2022; Kasule et al., 2023). The crop is primarily grown for its grain, which serves as food, providing over 65% of the carbohydrate requirements and 30% of the daily calorie intake for humans (Gupta et al., 2017). The stover is used for livestock feeding. Finger millet grains are rich in micronutrients, antioxidants, and dietary fiber, which promote health and nutritional well-being (Ojulong et al., 2021; Abioye et al., 2022). The crop is gluten-free making it a premium special diet for people with diabetes and gluten-sensitive consumers (Ojulong et al., 2021). In addition, finger millet has strong cultural roots where it is considered a special meal in all cultural functions like marriage, naming of the children, and celebrating new harvest festivals (Wanyera, 2005).

The demand for finger millet is on the rise both at local and international levels (Gierend et al., 2014; Orr et al., 2016, 2020). This is due to its climate resilience and drought tolerance characteristics; the crop requires less water to complete its growth cycle, making its production more sustainable (FAO, 2019; Choudhary et al., 2023). The crop can withstand high temperatures up to 44°C, at which other cereals like maize and rice cannot grow (Yogeesh et al., 2016; Mwangoe et al., 2022). In addition, the rising population coupled with changing lifestyles, and rapid urbanization create opportunities for the development of diversified millet food products according to taste requirements, and convenience for traditional and modern consumers such as ready-to-eat foods or food for diabetics, hence widening the demand (Orr et al., 2016, 2020). Given the health benefits of millet, private companies are taking up the commercialization of millet-based products. For example, bushera (a non-alcoholic soft drink made from millet) is currently processed and packaged by both small and big companies such as Century Bottling Company in Uganda (Mubiru et al., 2020; Kasule et al., 2023). These types of finger millet products need the development and release of finger millet varieties that have traits for the specific niche market but also ensure sustainable production and productivity to balance supply with demand (Kasule et al., 2023).

Finger millet production is largely done by small-scale farming households with no access to inputs like improved seeds, fertilizers, pesticides, or improved implements (Wanyera, 2005; Adikini et al., 2021). All the production is done at a subsistence scale and purely rain-fed (Adikini et al., 2021). The current average productivity of finger millet at farmer fields is 0.6 t/ha (UBOS, 2022), which is very low compared to 3.5 t/ha obtained on-station. This low yield is a result of several factors including biotic stresses (like finger millet blast disease, parasitic striga weed), abiotic stresses (like drought, erratic rainfall, and declining soil fertility), limited availability and access to quality improved seed by farmers and poor agronomic practices leading to drudgery (Owere et al., 2014; Adikini et al., 2021; Kasule et al., 2023). In addition, finger millet is faced with low adoption of improved varieties and a lack of variety replacement (Owere et al., 2014, 2015). Over 60% of farmers are still using landraces which they recycle every season (Adikini et al., 2021; Kasule et al., 2023). Often, many of these landraces are inferior in yield, not well adapted to emerging climatic effects, and are prone to pests and diseases (Adikini et al., 2021; Kasule et al., 2023). To address the above challenges, over twelve improved finger millet varieties have been released in Uganda (Adikini et al., 2021). Notably, varieties such as SEREMI 2 (U15) and PESE 1 (P224) have been widely adopted by farmers both in Uganda and across East Africa (Kenya and Tanzania) largely because of their attributes like early maturity, big fingers, attractive colors, more tillers, good brew, and bread (Mwema et al., 2017; Orr et al., 2020; Ojulong et al., 2021; Tracyline et al., 2021). Finger millet varieties ENGENY, GULU E, and SERERE 1, released in the early 1970s, had very low adoption largely because of the poor yield (Gierend et al., 2014; Kasule et al., 2023). Similarly, varieties SEREMI 1 and 3 despite having high yield, were not adopted by farmers because they lacked brewing quality and the taste of the bread was poor (Gierend et al., 2014).

Variety adoption is a complex process and any new variety that does not address farmer preferences and production constraints is less likely to be adopted (Kasule et al., 2020). This is simply because farmers are specific in their decision making which can play a role in determining whether a variety or technology can be adopted (Cagley et al., 2009; Weltzien et al., 2019; Sanya et al., 2020). The lack of a systematic breeding process that incorporates traits preferred by farmers has been reported to result in poor performance and low adoption rates of new varieties, by farmers, especially by farmers in marginal environments (Gierend et al., 2014; Acevedo et al., 2020; Mireri et al., 2023). This therefore implies wasted efforts and resources given the years it takes to develop and release a variety. Understanding the trait characteristics preferred by farmers and other stakeholders in the value chain is key in defining product profiles needed to develop new varieties and therefore offers great potential for adoption. Currently, the traits preferred in finger millet varieties by farmers are not well defined, and very scanty information is available which limits the ability of breeders to incorporate such traits.

The research so far conducted on variety preference in finger millet has focused mainly on the preference of the farmers without considering the needs of other value chain actors like consumers (Owere et al., 2014). Although finger millet has long been considered a food security crop (Wanyera, 2005), the monetization of the economy forces farmers to sell part of the crop to satisfy their needs. The implication is that farmers may produce finger millet to suit the needs and preferences of other end users that may be different from theirs. Genetic modification of crops without considering consumer traits can lead to a rejection of new varieties. For example, discoloration of endosperm due to over-expression of ß-carotene is seen as a barrier to adoption for certain food crops (Polycarpe Kayodé et al., 2005). Also, consumers at different nodes have different trait needs. For example, millers prefer grain with good milling characteristics; while brewers desire grain that produces a good malt (Kiprotich et al., 2014). Consumers' quality perception of grains and derived foods needs to be incorporated into breeding programs to successfully enhance the adoption of improved varieties. Information on consumer traits in finger millet is lacking and needs to be identified, documented, and incorporated into product profiles to guide breeders during the breeding process. This will allow the integration of consumer traits at an early stage of variety development.

Variety choices and trait preferences are also influenced by gender (Cagley et al., 2009; Frimpong et al., 2023; Zimba et al., 2023). Studies have shown that trait preferences by men and women farmers may differ, especially when they are faced with different constraints, different roles and responsibilities in production and consumption systems, and different crop production goals (Weltzien et al., 2019; Andiku et al., 2021). Women and men have unequal access to and control over production resources like land which affects their decision on the choice of variety to plant (Weltzien et al., 2019). According to Cagley et al. (2009), farmers in most finger millet growing areas practice a patrilineal system of land ownership and men decide how a given land is used. The size of land and other productive resources will affect the choice of variety grown by women and men. According to Nchanji et al. (2021), most women tend to grow landraces because of their availability, affordability, and accessibility while men tend to adopt and grow improved varieties. Given the limited access to and control over resources by women, studies have also shown that women tend to focus more on food security-related traits like early maturity, multiple harvests, production potential during the full growing season as well as productivity under sub-optimal soil fertility (Christinck and Kaufmann, 2017).

Women are also keen on post-harvest processing and food preparation traits including storability, grain color, and texture (Weltzien et al., 2019; Frimpong et al., 2023). On the other hand, men tend to focus more on production and marketing-related traits (Frimpong et al., 2023; Zimba et al., 2023). Gender differences also affect how crops are utilized in postharvest and food processing and marketing and how these are valued by different consumer groups (Weltzien et al., 2019). Previous studies on other crops like cassava, sweet potato, and banana, indicated that gender differences in needs, access, and roles play a big role in the adoption of improved crop technologies including varieties (Tufan et al., 2018; Sanya et al., 2020, 2023; Polar et al., 2021). Finger millet is not an exemption to this trend; thus, the need to integrate gender in all breeding activities to ensure the needs of the end user are integrated into new varieties.

Therefore, the study was undertaken to identify and profile varietal traits desired by finger millet farmers and consumers and how these traits vary among women and men in the finger millet value chain. This study also dissects how socio-economic characteristics affect the trait preference of finger millet farmers. This information will be used to refine the product profiles and guide a variety development processes, recommendations, and deployment strategies by the Finger Millet Improvement Program in Uganda. Ultimately the new improved variety of finger millet will have the right traits needed by end users and this will increase adoption leading to increased yields, hence, improved food and nutrition security and income among smallholder farmers especially those in climate change-prone areas.

2 Materials and methods

2.1 Description of the study areas

The study was conducted in the Northern and Western regions of Uganda covering three districts, namely Bushenyi located at 0°31'59.99" N and 30°10'60.00″ E (Western Uganda), Nwoya located at 2°38'3.59" N and 32°00'0.00″ E and Lira located at 2°16'26.40″ E (Northern Uganda). The three districts were selected because they are among the leading finger millet-producing areas in Uganda.

2.2 Geospatial maps

The displayed maps were generated using the geographic information system software QGIS version 3.30.[1] Shape file data for the locations of the study area were obtained from the Uganda Bureau of Statistics (2023) spatial data portal. To place the geo-referenced study sites, the Datum of World Geodetic System 1984 (WGS84) was used to maintain consistency in datasets during analysis (Kumar, 1988). The map highlights major sites for growing finger millet in the corresponding agroecological zone (Figures 1, 2). The major nine agroecological zones depicted on the map were derived from a classification system that considers factors such as climate, soil type, vegetation, and socio-economic and cultural characteristics (MAAIF, 2018).

2.3 Study design

The study employed mixed methods research, incorporating both qualitative and quantitative methods to capture the preferred traits for finger millet by the farmers. The study mainly involved both men and women smallholder finger millet farmers in the selected districts.

2.4 Selection of study sites and sampling method

Multistage random sampling was used to arrive at the household level. In the first stage, the selection of regions was based on literature and production statistics data sources (UBOS, 2022). The major finger millet-producing regions were identified as the eastern, western, and northern regions in Uganda. For this study, western and northern regions were selected because little or no information regarding trait preference for these regions exists. Most of the studies so far conducted concentrated in the eastern region (Owere et al., 2014). In the western and northern regions, major finger millet-producing districts were selected based on production statistics. Bushenyi district in Western, and Lira and Nwoya districts in Northern regions were selected. Two finger millet growing sub-counties from each district were selected with the help of district production and marketing officers of the respective districts. A systematic random sampling was used to select 23–40 households per sub-county making a total of 173 households for the quantitative survey (Table 1). The respondents were purposively selected using an interval of five households with the help of local leaders and agricultural extension officers familiar with the area. From each household, one respondent who had experience in finger millet production was selected and interviewed. For households where both the household head and spouse were knowledgeable and actively involved in finger millet production, the household head was selected for interviewing.

2.5 Data collection methods

2.5.1 Quantitative data collection

The quantitative data were collected through a formal survey using semi-structured questionnaires. A total of 8 enumerators (4 women and 4 men) were trained on the designed survey tool. This was done to improve efficiency and accuracy in data collection and clarity in elaborating questions to respondents. The questionnaire was pretested with 10 finger millet farmers in Ongino subcounty in Kumi district who share similar characteristics with farmers in the study

1 https://www.qgis.org/en/site/forusers/download.html

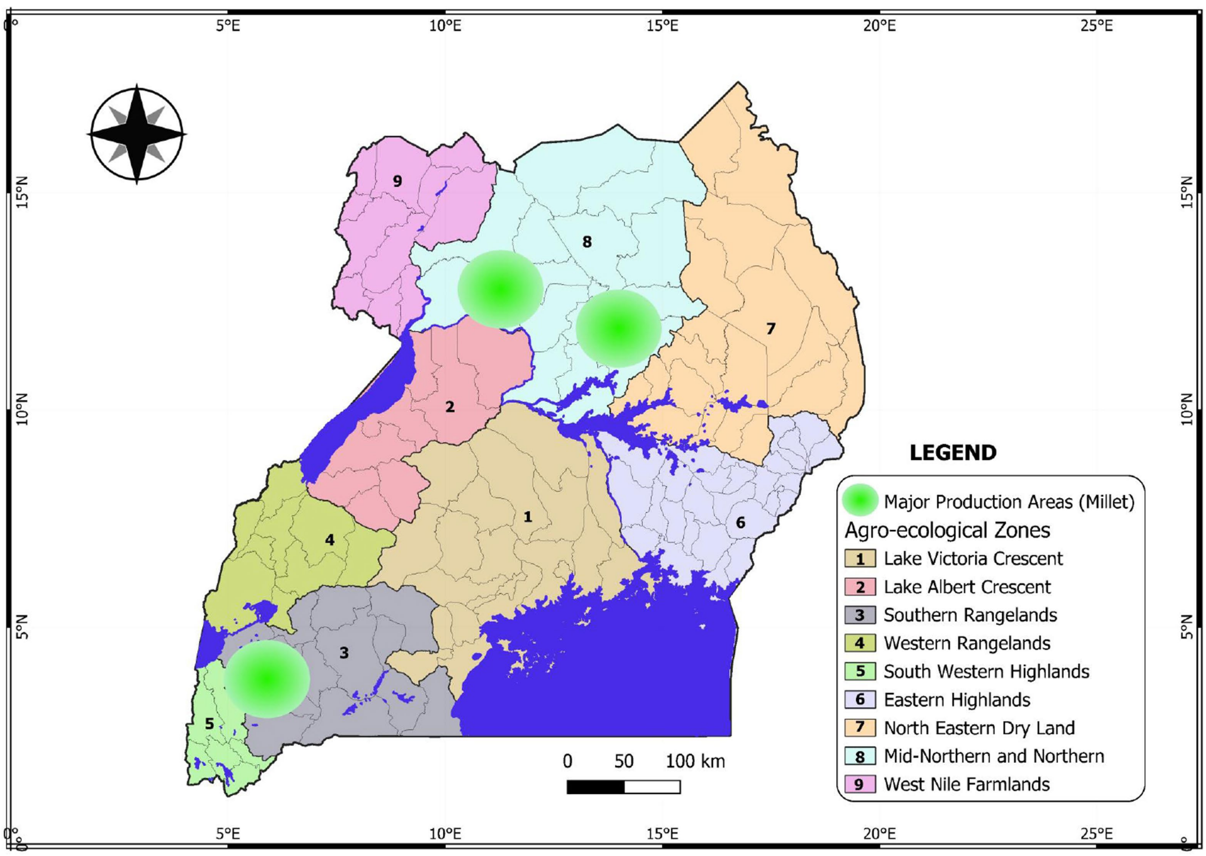

FIGURE 1
Showing a map of Uganda indicating the major finger millet growing areas.

areas and amendments were made to the study tool. Data were collected on the demographic and socioeconomic characteristics of the households, finger millet production system, variety grown, millet trait characteristics preferred by farmers, and socio-economic factors that affect trait preference and consumer sensory attributes. The survey questionnaire was automated using an open data kit (Kobo Collect).

2.5.2 Qualitative data collection

This study also used qualitative research methods to validate the data from the quantitative methods described above. Two methods were used, i.e., Focus Group Discussions (FGDs) and Key Informant interviews (KIIs).

2.5.3 Focus group discussions

FGDs were conducted purposely with farmers to get in-depth sex-disaggregated trait preference information. To guide the discussions, an FGD question guide was developed. The tool was pretested with farmers in finger millet growing districts as described above. Four facilitators (2 females, and 2 males) were identified and trained to conduct the FGDs. In each study district, a total of four (2 women and 2 men only) sex-disaggregated FGDs were conducted. However, the data for one of the men FGD from Bushenyi district was lost hence giving a total of 11 FGDs instead of 12 as earlier planned. Each FGD had 8–12 participants who were selected based on their knowledge of finger millet production with the help of an area extension officer. Before the start of the discussion, the research team (i.e., a facilitator and a note taker) introduced themselves to the participants and the purpose of the research was also properly explained. Consent was sought from all the participants and the guidelines that would guide the discussion were laid out to the participants to ensure proper sharing of ideas. The participation of the participants was voluntary and they were allowed to opt out of the FGD at any time with no penalty. Also, participants' consent to record the interview and take photos was sought. An audio recorder was used to record the discussion. Each participant was assigned a code to avoid others referring to them by their name. During the discussion, every participant was given an equal opportunity to actively share their views. The FGDs centered around finger millet production systems, uses, roles, and responsibilities of men and women in finger millet production, practices used by farmers, and farmers' trait preferences and challenges faced during production.

2.5.4 Key informant interviews

One key informant interview was conducted in each district with the district production and marketing officer who oversees all the extension activities in the district giving a total of three KIIs. Key informant interviews were conducted before household surveys and focus group discussions (FGDs). The information generated guided the development of questionnaires and FGD guides as well as getting a deeper understanding of finger millet production from the perspective of the knowledgeable people in the district. A flexible

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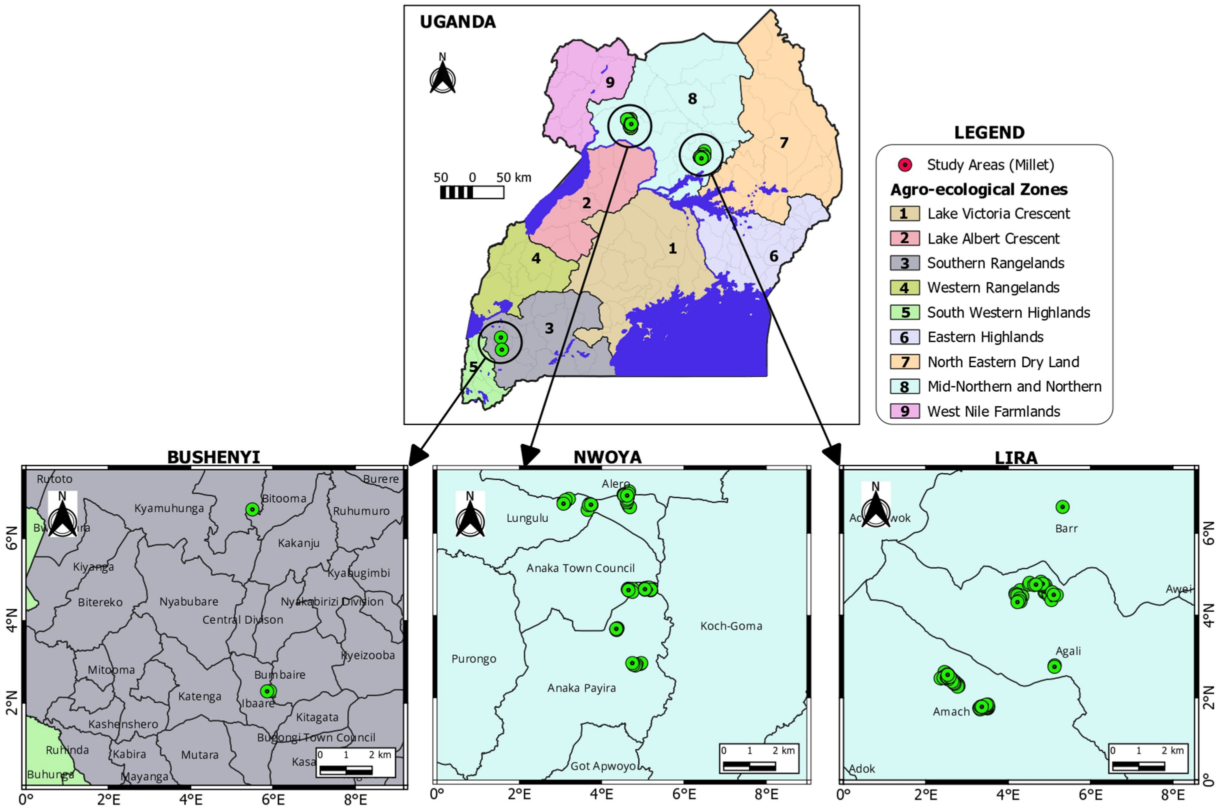

FIGURE 2
Showing the different agro-ecological zones with areas where the study was conducted.

TABLE 1 The number of households sampled per district.

Region	Districts	Sub Counties	Number of households sampled
Northern	Lira	Agali	23
Northern	Lira	Amach	26
Northern	Nwoya	Anaka	26
Northern	Nwoya	Lungulu	29
Western	Bushenyi	Ibaale	40
Western	Bushenyi	Kyamuhunga	29
		Total	173

checklist with open-ended questions was used to interview key informants. This generated information on finger millet production systems, trait preferences, and challenges faced by farmers during finger millet production.

2.6 Data management and analysis

Data from Kobo collect was exported to and cleaned in Excel. Data was coded and analyzed using the statistical package for social scientists (IBM SPSS version 29.0, 2022) using descriptive statistics on both quantitative and qualitative datasets to produce graphs. Multiple response data for varieties and farmer traits were grouped using the multiple response command of SPSS. To analyze relationships between variables; contingency chi-square tests were used to make statistical inferences at a 0.05 level of significance. Finger millet farmer-preferred attributes were subjected to principal component (PC) analysis based on eigenvalues greater than 1.0 by performing multiple response analyses to generate attribute frequencies of respondents which were later used for principal component analysis (PCA). Results were presented as percentages in bar graphs and tables. A *t*-test was performed in SPSS to assess significant differences in preferred traits between male and female respondents.

A Probit regression analysis was performed using the statistical software Stata version 14 to examine the factors influencing farmers' choice of finger millet. Probit regression is a statistical method commonly used to analyze binary outcomes, where the dependent variable can take only two values (in this case, "Choice of the trait" or "No Choice of the trait"). The model helped in understanding the relative importance of different variables in influencing the decision-making of millet farmers. The analysis assumes that the decision-making process follows a latent continuous variable that is not directly observed but can be related to a set of explanatory variables through a cumulative distribution function called the standard normal distribution.

The equation structure of the Probit model can be represented as follows:

$$\Pr\left(Yi=1\right)=\Phi\left(\beta 0+\beta 1X1i+\beta 2X2i+\ldots+\beta nXni\right)$$

Where:

Pr ($Yi = 1$) is the probability of choosing the trait for the ith farmer.

Φ represents the cumulative distribution function of the standard normal distribution.

$\beta 0, \beta 1, \beta 2, \ldots, \beta n$ are the coefficients to be estimated.

$X1i$, $X2i$, …, and Xni are the independent variables for the ith farmer.

In this case, the dependent variable (Yi) is the choice of trait for finger millet (either "Choice of trait" or "No Choice of trait"). The independent variables ($X1i$, $X2i$, …, Xni) include sex, education, marital status, farming experience, occupation, and household size. These independent variables were assumed to influence the farmers' decision-making process regarding which millet traits they chose. The Probit regression was performed for eight trait characteristics: big head, big grain size, disease resistance, early maturity, high yielding, high market demand, taste, and drought tolerance. The model's estimation allows you to analyze the relationship between these trait characteristics and the farmers' decision-making process while controlling for the impact of the independent variables on their choices.

For qualitative data, all the audios were transcribed verbatim and all the notes taken during the FGDs were consolidated to ensure that what exactly happened in the field was well documented. Transcripts were cleaned and coded manually to generate themes. After the analysis, both qualitative and quantitative findings were integrated.

3 Results

3.1 Demographic and socio-economic characteristics

The information generated during this study was obtained from farmers who had been cultivating finger millet for a period ranging from 1 to 50 years or more (Figure 3). Bushenyi and Lira districts recorded the longest period of finger millet cultivation in the study area while Nwoya had the shortest period of finger millet cultivation.

In this study, the majority of finger millet farmers own land and others have access to land for growing the crop in the surveyed districts (Figure 4). A few farmers who need extra land for finger millet cultivation, rent 2–3 acres of land to supplement what they own (Figure 4).

The demographic and socio-economic attributes of respondents and their households in each district are summarized in Table 2. Out of the 173 survey respondents, 61.3% were female while 38.7% were men. In study areas, 62.8% of the respondents were in the ages of 26–50 years, with only 12.1% of the respondents below 25 years of age, whereas 25.1% were above 50 years of age. Most respondents were married (monogamous) and significantly ($X^2 = 180.96$, $p = <0.001$) more than the polygamous and widowed. There were no respondents who were single or divorced in the surveyed areas. A majority (56.4%) of the survey respondents achieved at least primary education and were significant ($X^2 = 189.13$, $p = <0.001$). In comparison, 21.3% attained a maximum of secondary education (21.3%), however, 19.4% of the respondents interviewed never went to school for any formal education (Table 2). The differences in the main occupation of the respondents across study sites were significant ($X^2 = 191.6$, $p = <0.001$), with most respondents (86.1%) earning their living on crop farming followed by self-employed or on-farm businesses (5.5%).

3.2 Finger millet production systems

Detailed descriptions of finger millet production systems in surveyed areas are presented in Table 3. The majority (96.9%) of finger millet farmers plant landraces with only 3.1% using improved varieties ($X^2 = 176.9$, $p = <0.001$). The primary purpose (72.5%) of finger millet varieties grown in study areas was for food and income ($p = <0.001$). 23.6% responded that finger millet is cultivated mainly for food home consumption and 3.9% grow finger millet for sale only to obtain income (Table 2). On average, 79.2% allocated 1 acre for sole cultivation of finger millet ($X^2 = 23.3$, $p = 0.003$), followed by 2 acres (15.6%), 3 acres (2.9%), and least on 4 acres (1%) in 2021. A total of 70.1% of the respondents use their home-saved seed ($X^2 = 178.7$, $p = <0.001$). Farmers also access finger millet seed from open markets (22.9%), fellow farmers (4.9%), and least from Non-Government Organizations (NGOs) (Table 3).

3.3 Major finger millet varieties grown and farmers' trait preferences in Uganda

Generally, farmers consider traits like early maturity (271.8%), high yields (231.1%), drought tolerance (229.5%), taste (209.5%), big heads (196.7%), and high market demand (121.3%) across the surveyed areas (Table 4). In Western Uganda (Bushenyi district), early maturity (87%), taste (81.2%), and high yields (79.7%) were the most preferred traits. In northern Uganda, early maturity (93.9%), drought tolerance (79.6%), and high yields (71.4%) were the most preferred traits in Lira district while in Nwoya district attributes like early maturity (90.9%), drought tolerance (81.8%), and high yields (80%) were preferred by farmers (Table 4). The least preferred attributes in all surveyed areas were good brewing characteristics, striga resistance, faster fermentation properties, heavy brew, and small grain size among others.

From the 11 top-ranked desirable finger millet attributes, we assessed their patterns of variation and relative order of importance using principal component analysis (PCA) (Table 5). Each eigenvalue for the first four principal components (PC) was greater than 1.0 and cumulatively contributed to 56.4% of the variation in finger millet attributes among the respondent farmers (Table 5). Scores of PC1, which accounted for 18.7% of the total variation, were correlated to ($r > 0.45$) to pest tolerance (0.71), drought tolerance (0.59), big heads (0.52), disease resistance (0.51), and high market demand (0.47). PC2 explained 16.5% of the total variation with loading scores contributed by taste (0.67), medium plant height (0.53), and drought tolerance (0.51). Scores of PC3 contributed to the variation of 11.5% correlated with attributes such as easy to thresh (0.6), disease resistance (0.53), medium plant height (0.51), and high yields (−0.49) while at PC4, only attributes such as high yields (0.62) and big heads (−0.6) were discriminating contributing to 9.7% of total variation (Table 5).

From the focus group discussions, it was noticed during the discussion that farmers grow several finger millet varieties. In western Uganda, varieties mentioned by farmers included SEREM 2, Mahega, Mbanjura, Kabaragara, Kabumburi, Kabukunguru, Kagume, and Nkodere. In Northern Uganda, some of the varieties mentioned by farmers were Ajuko manyige, Okello chiba, Okama, Kal atar, Todyang, Okama lango, and Agun kibati. The top-ranked varieties grown by farmers in western and northern Uganda and their preferred attributes are presented in Table 6. Farmers identified local landraces as

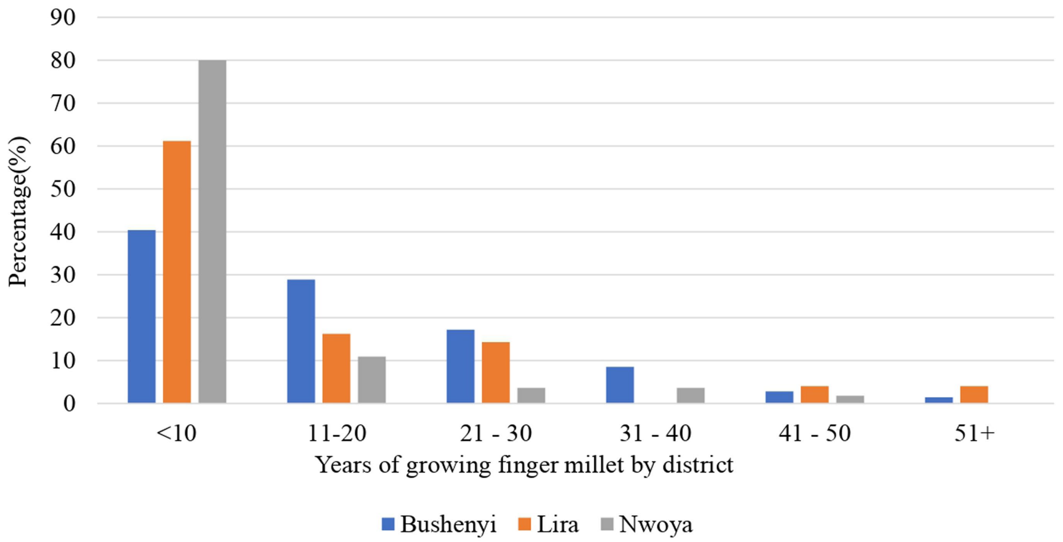

FIGURE 3
Duration of finger millet cultivation by farmers in the study areas.

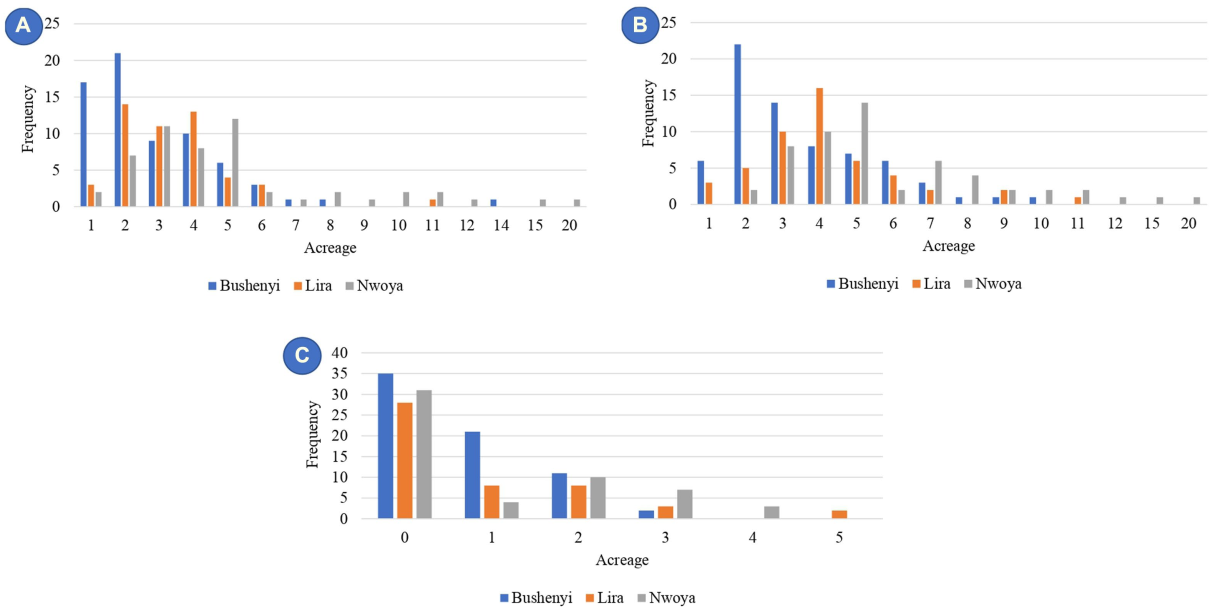

FIGURE 4
Farmer responses about land ownership **(A)**, access to agricultural land **(B)**, and land rented **(C)**.

preferred finger millet varieties by their local names. These were Kagume from the western region and Ajuko Manyige and Kal Atar from the northern region. Farmers highlighted attributes as to why they prefer these varieties for food and porridge, some for both food and making the local brew, while a few were not conducive for food but only alcohol. During focus group discussions, it is therefore understandable why some varieties with non-preferred attributes were rejected by farmers like the Kashema variety in western Uganda. Furthermore, in the same region farmers prefer the variety, Kisansha, because of its soft stem and therefore, easy to harvest. This variety is easy to harvest by hand rather than using a knife, hence less laborious besides other attributes.

3.4 Gender differences in finger millet traits preferred by farmers and consumers

Gender differences in finger millet traits preferred by men and women while growing the crop in Uganda are presented in Table 7. Using a *t*-test, significant variations were observed in preferred

TABLE 2 Socio-demographic characteristics of smallholder finger millet farmers in Western and Northern Uganda.

Variable	Class	Western Uganda	Northern Uganda		Mean	Chi-Square	df	*p*-value
		Bushenyi (*n* = 69)	Lira (*n* = 49)	Nwoya (*n* = 55)				
Sex	Women	52.2	73.5	58.2	61.3	5.55	2	0.06
	Men	47.8	26.5	41.8	38.7			
Age (year)	<25	7.2	16.3	12.7	12.07	4.57	4	0.33
	26–50	62.3	57.1	69.1	62.83			
	>50	30.4	26.5	18.2	25.1			
Marital status	Married (Monogamous)	91.3	83.7	85.5	86.83	180.96	9	<0.001
	Married (Polygamous)	4.3	6.1	12.7	7.70			
	Widowed	4.3	10.2	1.8	5.43			
	Divorced/Separated	0	0	0	0.00			
	Single	0	0	0	0.00			
Education level	No formal education	23.2	22.4	12.7	19.43	189.13	18	<0.001
	Primary level	53.6	61.2	54.5	56.43			
	Secondary (A-Level)	1.4	2	0	1.13			
	Secondary (O-Level)	18.8	14.3	27.3	20.13			
	Tertiary/University	2.9	0	0	0.97			
	Vocational	0	0	5.5	1.83			
Main occupation	Business/self-employed (off-farm)	8.7	4.1	3.6	5.47	191.6	24	<0.001
	Casual laborer	5.8	2	1.8	3.20			
	Civil servant	4.3	0	1.8	2.03			
	Crop farming	73.9	91.8	92.7	86.13			
	Driver	1.4	0	0	0.47			
	Engineer	1.4	0	0	0.47			
	Livestock farming	4.3	2	0	2.10			

traits for only yield ($p = 0.039$). The top five traits preferred by female finger millet farmers were early maturity (92.3%), drought tolerance (73.1%), taste (73%), high yielding (72.1%), and big heads (66.4%). Male finger millet farmers preferred varieties with traits like early maturity (87%), followed by high yielding (85.5%), drought tolerant (79.7%), taste (68.1%), and big heads (63.8%). Both men and women mostly preferred finger millet varieties that are early maturing.

The study also revealed differences between men and women in sensory trait preferences and cooking quality characteristics for finger millet consumption (Table 8). Men (60.9%) showed a stronger preference for good cooking quality compared to women (39.4%) with a statistical significance ($p = 0.006$). However, both men and women largely agreed on the trait of good taste (97.1%). There were no significant differences in other consumer traits like short cooking time, use of little flour to mingle, and making good color when mixed with cassava between men and women. Although a high percentage of men (85.5%) prefer nice aroma compared to women (77.9%), this difference was not statistically significant ($p = 0.21$). Similarly, the cooking quality characteristic 'dough stickiness' shows minimal gender differences (reported by 21.2% women, and 20.3% men) with no significant variation ($p = 0.89$). Both men and women consumers mostly prefer millet with a good taste. Three-quarters of the millet consumers reported good taste and nice aroma as their preferred sensory attributes.

3.5 Probit regression results

3.5.1 Big head trait preference

Among all the socioeconomic factors presented in the model, the results showed that gender, marital status, experience in growing millet, age, and household size did not significantly ($p > 0.05$) influence the preference for big heads among finger millet farmers (Table 9). Education at primary, secondary, and tertiary levels significantly ($p < 0.05$) influenced big head trait preference compared with no education. However, there was a decreasing odds ratio from lower (0.3) to higher education (0.03) for preferring big heads as compared to having no education.

3.5.2 Big grain size

Marital status, experience in growing millet, age, primary and secondary education levels, and household size did not significantly ($p > 0.05$) influence the preference for big grain size among finger millet farmers (Table 9). However, gender and having tertiary education had marginal statistical significance (0.06) in explaining

TABLE 3 The finger millet cropping system of the surveyed households in northern and western Uganda.

Variable	Class	Western Uganda	Northern Uganda		Chi-Square	df	*p*-value
		Bushenyi ($n = 69$)	Lira ($n = 49$)	Nwoya ($n = 55$)			
Variety grown	Improved	5.8	0.0	3.6	176.90	6.00	<0.001
	Local	94.2	100.0	96.4			
Land size where millet was grown in 2021 (acres)	1	92.8	77.6	67.3	23.25	8.00	0.003
	2	2.9	20.4	23.6			
	3	1.4	0.0	7.3			
	4	2.9	0.0	0.0			
	5	0.0	2.0	1.8			
Seed source	Fellow farmers	7.20	2.00	5.5	178.67	12.00	<0.001
	Home saved seed	63.80	75.50	70.9			
	NGOs	4.30	0.00	1.8			
	Open markets	24.60	22.40	21.8			
The main purpose of finger millet grown	Food and income	58.0	79.5	80.0	208.02	12.00	<0.001
	Food	42.0	14.3	14.5			
	Income	0.0	6.1	5.5			

Df, degrees of freedom; NGOs, Non-Government Organizations.

farmers' choice for big grain size trait preference. For instance, being a woman had an odds ratio of 2.056 for choosing millet with a bigger grain size than men. Considering education, having a tertiary education had an odds ratio of 7.104, suggesting that individuals with tertiary education have a significantly higher odds ratio of choosing big grain size than those without education.

3.5.3 Disease resistance

There was a positive association between experience in growing finger millet and the likelihood of preferring disease-resistant traits (odds ratio of 1.02), although the association was not statistically significant ($p > 0.05$) (Table 9). Gender, marital status, and occupation do not appear to have statistically significant ($p > 0.05$) effects on the preference for disease-resistant traits among finger millet farmers. Primary and secondary education had an odds ratio of 0.292 and 0.246 respectively, indicating a lower likelihood of choosing disease-resistance traits than farmers without education, however, their effects were pronounced and statistically significant ($p < 0.05$). The age of farmers had an odds ratio of 0.967, indicating older farmers are less likely to choose disease-resistance traits for millet compared to young farmers and the relationship was statistically significant. Also, household size had an odds ratio of 1.215 and was statistically significant ($p < 0.05$) indicating that higher household size is associated with a higher preference for disease resistant finger millet varieties.

3.5.4 High market demand

Gender, education, and occupation of the farmer had a statistically significant ($p < 0.05$) relationship of choosing high market demand trait (Table 9). Women had approximately 47.6% lower odds of choosing finger millet varieties with high market demand compared to men. However, this association was marginally statistically significant ($p = 0.075$). Individuals having primary education, secondary education, and tertiary education had a lower odds ratio of choosing finger millet with high market demand compared to those with no education even though the differences were statistically significant for primary and secondary education levels at 0.05 and 0.01 levels of significance, respectively. Respondents whose main occupation is agriculture have approximately 141% higher odds of adopting high-market demand finger millet varieties than those with non-agricultural occupations farmers (Table 9).

3.5.5 High-yielding

Experience in growing millet, main occupation, age, and household size did not show significant effects ($p > 0.05$) on preference for high-yielding varieties (Table 9). Gender, marital status, and marginal education levels significantly influenced the preference for finger millet varieties with high-yielding characteristics. Women had approximately 63.2% lower odds of choosing finger millet varieties with high-yielding characteristics compared to men ($p < 0.05$). Also, married farmers were 742% more likely than unmarried farmers to choose high-yielding millet varieties ($p < 0.05$). Having secondary education compared to no education had an odds ratio of 0.226 ($p < 0.05$), indicating that farmers with secondary education are less likely to choose high-yielding millet variety compared to non-educated millet farmers.

3.5.6 Taste

Most of the factors like gender, marital status, experience in growing millet, main occupation, age, household size, and education levels significantly ($p > 0.05$) influenced the preference for finger millet varieties based on taste (Table 9). However, higher education (tertiary) was marginally significant ($p = 0.08$) for the taste trait.

3.5.7 Drought tolerance

Respondents with agriculture as their primary occupation were more likely to choose finger millet varieties that are drought tolerant

TABLE 4 Attributes that farmers put into consideration when selecting finger millet varieties in western and northern Uganda.

Preferred attribute	Bushenyi (%)	Lira (%)	Nwoya (%)	Rank
Early maturing	87	93.9	90.9	1
High yielding	79.7	71.4	80	2
Drought tolerant	68.1	79.6	81.8	3
Taste	81.2	59.2	69.1	4
Big head	62.3	65.3	69.1	5
High market demand	36.2	46.9	38.2	6
Disease resistance	47.8	32.7	29.1	7
Big grain size	24.6	44.9	27.3	8
Pest tolerant	17.4	34.7	36.4	9
Medium height varieties	29	34.7	16.4	10
Easy to thresh	17.4	24.5	29.1	11
Long storability	13	18.4	32.7	12
High flour yield	29	14.3	20	13
Takes long to feel hungry	1.4	20.4	27.3	14
Good bread colour	8.7	16.3	16.4	15
Easy to weed	1.4	20.4	14.5	16
Tall varieties	18.8	6.1	3.6	17
Resistance to birds	4.3	12.2	10.9	18
Lodging tolerance	0	10.2	14.5	19
Easy to grow	1.4	12.2	10.9	20
Red grain color	5.8	6.1	10.9	21
Short height of the variety	0	14.3	7.3	22
High dry matter content	7.2	4.1	5.5	23
Easy to grind	5.8	6.1	1.8	24
Can grow in poor soil	0	10.2	1.8	25
Small grain size	2.9	4.1	1.8	26
Heavy brew	0	2	3.6	27
Ferments fast	1.4	2	1.8	28
Resistance to Striga	2.9	2	0	29
Good brewing characteristics	1.4	0	0	30

than non-agricultural occupations respondents (odds ratio of 2.592), and the difference is statistically significant ($p < 0.05$). Women farmers have approximately 51.3% lower odds of choosing finger millet varieties with drought tolerance characteristics compared to men, with a marginally significant ($p = 0.099$) difference, suggesting a potential but not strong relationship (Table 9).

4 Discussion

4.1 Socio-demographic profile of finger millet farmers in Uganda

Finger millet is an ancient crop and this study showed that farmers who participated in the study had been cultivating the crop for periods ranging from 3 years up to over 50 years. This denotes the presence of

TABLE 5 Principal component analysis of major finger millet preferred attributes in surveyed areas in Uganda.

Variables	PC1	PC2	PC3	PC4
Early maturing	0.27	−0.35	0.01	0.25
High yielding	0.19	0.09	−0.49	**0.62**
Drought tolerant	**0.59**	**0.51**	0.1	−0.01
Pest tolerant	**0.71**	−0.25	0.32	−0.03
Taste	0.24	**0.67**	0	0.06
Big head	**0.52**	−0.11	−0.01	**−0.6**
High market demand	**0.47**	0.08	0.1	0.39
Easy to thresh	0.37	−0.31	**0.6**	0.22
Medium height	−0.34	**0.53**	**0.51**	0.09
Disease resistance	**0.51**	−0.03	**−0.53**	−0.16
Big grain size	−0.17	**−0.72**	0.05	0.13
Eigenvalue	2.06	1.82	1.26	1.07
Proportion of variance (%)	18.73	16.51	11.49	9.7
Cumulative variance (%)	18.73	35.25	46.73	56.43

PC, principal component, Boldface values denote high score values indicating the preferred finger millet attributes (>**0.45**).

knowledge of millet production dynamics over the years and increasing awareness of the crop's economic potential and importance hence attributing to the recent surge in finger millet cultivation in the study areas (Owere et al., 2014; Adikini et al., 2021; Kasule et al., 2023). Western Uganda appears to have a longer history and is more established in finger millet cultivation. This is in agreement with other researchers who attributed this long history to the Iron Age and domestication of finger millet which originated from the highlands of western Uganda (Fuller, 2014; Kasule et al., 2023).

Majority of the households in western and northern Uganda growing finger millet owned or had access to 2–3 acres of land. Furthermore, some farmers, despite owning and having access to land, choose to rent more land for finger millet cultivation (UBOS, 2022). This access and ownership of land underscores the importance of land as a resource in finger millet cultivation. Access to more farming land has been shown to improve food and income security among agricultural communities in Uganda (FAO, 2018). The amount of land allocated to finger millet production is less and could be attributed to the customary tenure system of land where women only access land through their husbands who own and make decisions on the land use. Given that the majority of respondents in this study were women (over 60%) compared to men, their response was based on household decisions concerning land ownership. Studies indicated that in a household, women consult their spouses and are more likely to report joint decision-making than men in crop farming (Gebreyohannes et al., 2021).

The predominance of women farmers in finger millet production compared to men in this study confirms earlier studies in Uganda (Owere et al., 2014; Otieno et al., 2021). Similar results were reported in other East African countries like Kenya, where 57% of the farmers producing finger millet were women (Mbinda et al., 2021). Studies in other crops have shown that the predominance of women in agriculture activity is associated with low productivity because women farmers have limited control and access to resources that influence

TABLE 6 Top finger millet varieties grown and their attributes preferred by farmers in western and northern Uganda.

Variety	Use	Preferred attributes	District	Farmers growing the variety (%)	Non-preferred attributes
Ajuko Manyige	Food	Early maturity (3 months), high-yielding, easy-to-grind, tasty bread, can be harvested before it fully matures	Nwoya ($n=55$)	56.4	none recorded
Kal Atar	Food and local brewing	Moderate yield, early maturity, marketable	Lira ($n=49$)	35	none recorded
Okello Chiba	Food and local brewing	Good brown colour, big head, tasty bread, tallness	Lira ($n=49$)	43	susceptible to lodging
Kagume	Food and local brewing	High-yielding, absorbs water, good bread	Bushenyi ($n=69$)	30	Requires fertile soils, liked by birds

TABLE 7 Finger millet traits preferred by men and women while growing the crop in Uganda.

Attributes	Female (%)	Male (%)	*p*-value
Big head	66.4	63.8	0.729
Big grain	35.6	63.8	0.13
Disease resistance	35.6	40.6	0.509
Medium height variety	27.9	24.6	0.638
Early maturing	92.3	87	0.25
Resistance to birds	11.5	4.4	0.101
High yielding	72.1	85.5	0.039
High market demand	36.5	44.9	0.273
Resistance to Striga	1	2.9	0.342
Taste	73	68.1	0.484
Long storability	22.1	18.8	0.606
Easy to thresh	25	20.3	0.475
Lodging tolerance	8.7	5.8	0.488
High flour yield	23.1	20.3	0.667
Easy to weed	12.5	8.7	0.436
Good bread color	11.5	15.9	0.407
Takes long to feel hungry	15.4	14.5	0.873
Ferments fast	2.9	0	0.157
Red color	5.7	8.7	0.461
Pest tolerant	27.9	29	0.876
Drought tolerant	73.1	79.7	0.322
Easy to grind	6.7	1.5	0.107

TABLE 8 Gender differences in sensory and cooking attributes preferred by finger millet consumers in Uganda.

Trait preference	Percentage responses (%)		*p*-value
	Women	Men	
Good taste	97.1	97.1	0.996
Good cooking quality	39.4	60.9	0.006
Short cooking time	51.9	58	0.437
Use little flour to mingle	49	56.5	0.338
Make good color when mixed with Cassava	48.1	58	0.204
Nice aroma	77.9	85.5	0.214
Sticky	21.2	20.3	0.892

production and productivity (Gebreyohannes et al., 2021). In addition, finger millet is a labor-intensive crop and women perform most of the tedious and time-consuming manual activities justifying the low productivity observed at farmer fields. Proper measure to address this gender gap in finger millet is needed to increase crop production and productivity. One of the strategies is the development, testing, and outscaling of labor-saving machinery in the entire production chain as in the case of Nepal (Devkota et al., 2016).

This study found that the majority of finger millet farmers were within the age group of 26–50 years which is considered the most productive age for any agricultural activity in Uganda (Owere et al., 2014; Mwema et al., 2017; Andiku et al., 2021). This age group has productive and energetic farmers who participate in the economy by providing labor and engaging in economic activities, such as trade and decision-making (UBOS, 2022). They are likely to expand finger millet production and adopt the use of inputs like improved seeds, fertilizers, and better agronomy hence increasing productivity and output.

The study also revealed that the majority of the households rely on crop farming as their primary occupation. This is attributed to Uganda's dependence on agriculture for both food and income security. In addition, a great deal of the study respondents were married and this marital status helps to determine the level of participation in decision-making along with the finger millet production and marketing chain (UBOS, 2022). In Uganda, married farmers have better ownership of production resources like land and are likely to adopt new technologies like improved varieties (Doss et al., 2011). Other studies have also found that marital status of the household head has a significant influence on the adoption of improved crop varieties (Atube et al., 2021). The majority of these respondents had significantly lower levels of education up to the primary level. The low level of education among finger millet producers is of concern, especially for the successful introduction of new technologies and dissemination of information. A low level of education has been identified as a significant factor leading to poor adoption of agricultural technologies and access to information in rural and smallholder farming communities (Fadeyi et al., 2022). An

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TABLE 9 Socio-economic factors that affect finger millet trait preference.

Variables	Bighead		big grain size		Disease resistance		High market demand		High yielding		Taste		drought tolerance	
	Odds Ratio	*p*-value	Odds Ratio	*p*-value	Odds Ratio	*p*-value	Odds Ratio	*p*-value	Odds Ratio	*p*-value	Odds Ratio	*p*-value	Odds Ratio	*p*-value
Sex (base: male)														
Female	0.686	0.343	2.056	0.064	0.722	0.376	0.524	0.075	0.368	0.029	0.872	0.724	0.487	0.099
Marital status														
Married (base: unmarried)	0.502	0.479	1.329	0.759	1.337	0.754	1.065	0.94	8.42	0.016	0.222	0.2	0.191	0.172
Education (base: no education)														
Primary	0.313	0.041	1.449	0.433	0.292	0.006	0.407	0.04	0.592	0.371	0.443	0.119	0.692	0.49
Secondary	0.072	<0.001	2.091	0.201	0.246	0.013	0.195	0.004	0.226	0.028	0.364	0.106	0.392	0.147
Tertiary	0.033	0.007	7.104	0.061	0.138	0.117	0.123	0.086	0.308	0.361	0.149	0.079	0.281	0.25
Experience in growing millet	0.992	0.67	1.007	0.724	1.016	0.429	0.978	0.232	0.992	0.728	1.012	0.547	0.985	0.478
Main Occupation (Non Agric)														
Occupation_Agric	2.112	0.131	0.986	0.977	2.098	0.163	2.41	0.093	0.88	0.815	0.531	0.255	2.592	0.047
Age of respondent	0.972	0.152	0.999	0.936	0.967	0.063	0.981	0.247	1.01	0.641	0.973	0.143	0.971	0.136
HH size	0.995	0.956	1.058	0.495	1.215	0.02	1.027	0.743	0.95	0.593	0.979	0.803	1.042	0.645
Number of obs	173		173		173		173		173		173		173	
LR chi2(9)	28.64		7.39		21.47		18.16		15.9		10.77		13.76	
Prob > chi2	0.001		0.596		0.011		0.033		0.069		0.292		0.131	
Pseudo R2	0.128		0.034		0.094		0.078		0.086		0.052		0.072	
Log-likelihood	−97.342		−103.701		−103.777		−107.271		−84.382		−98.635		−89.006	

innovative approach of technology transfers especially through farmer field schools where farmers learn by seeing and doing needs to be used in promoting improved finger millet varieties to farmers with low levels of education.

4.2 Finger millet production and cropping systems

Results indicate that only a small proportion (3.1%) of the surveyed farmers were growing improved varieties. This is consistent with most adoption studies for different crop varieties that show low use of improved varieties and farmers' continued use of their landraces alongside improved varieties for various reasons (Katungi et al., 2011; Ainembabazi and Mugisha, 2014; Sanya et al., 2020).

The low use of improved finger millet varieties could be attributed to a mismatch between current varietal traits and farmers' preferences thus failure to meet their diverse needs and demands. This could also be explained by the failure of existing seed systems to deliver the improved varieties to farmers since most farmers (>70%) also reported that they were using their home-saved seed. However, most of these landraces preferred by farmers are often low yielding, late maturing, and tall (susceptible to lodging) (Adikini et al., 2021; Kasule et al., 2023). The finger millet breeding programme therefore needs to prioritize farmers' preferences in the breeding process if the use of improved finger millet varieties is to be accelerated. Integration of actors in the seed system chain will also be useful to ensure that the varieties reach the end-users. Additionally, the results showed that over 70% of the farmers grow finger millet for food and income which could be explained by the high market demand of this crop, thus its potential to contribute to better livelihoods of the diverse and vulnerable groups in fragile ecosystems.

4.3 Finger millet varietal and trait preferences across regions and gender

There were variations in finger millet landrace varieties preferred by farmers in different locations as evidenced from this study. During FGD, farmers revealed that they grow more than one finger millet variety in their field to mitigate the risk of loss due to harsh weather. They further revealed that millet varieties serve different purposes such as brewing, food, or for sale. Farmers' preference for local landraces is in agreement with earlier findings that most landraces are well adapted to low-input farming systems and possess essential quality traits (Orr et al., 2016). Among the traits that farmers use for selecting and adopting the varieties, early maturity was ranked first as the most preferred finger millet trait in both western and northern Uganda. Early maturing crop varieties can yield a positive harvest within a short period of planting to protect farmers in case of low rainfall or drought. This means farmers are aware of the climate changes and the marginal environment where this crop is grown. In addition, multiple cropping can be achieved in small piece of land to ensure food and nutrition security given that most finger millet farmers own less than 5 acres of land.

The prioritization of subsequent traits varied across locations. In western Uganda, taste ranked second followed by high yield, drought, and big head probably because finger millet is produced mainly for food purposes. The most preferred variety in this region was land race Kaguma, because of its high yields, good water absorption properties during cooking, and suitability for making good bread as was reported in the focus group discussion. Studies in other crops, such as maize and sorghum, have similarly highlighted the influence of taste, marketability, and agronomic traits in shaping farmers' variety choices and trait preferences (Mwema et al., 2017; Orr et al., 2020; Andiku et al., 2021; Habte et al., 2023). This implies the need for the integration of consumer traits along with agronomic traits during the breeding process. Lack of variety adoption has been linked to poor taste in some of the earlier released finger millet varieties (Gierend et al., 2014).

In northern Uganda, however, drought tolerance was ranked second followed by high-yield, big head, and test. This could be because the region tends to have long drought spells and unpredicted rainfall. Having variety with such traits guarantees food security and mitigates the effect of climate change in the region (Oduori, 2008; FAO, 2019; Kasule et al., 2023). In FGD, it was revealed that farmers in this region particularly in Nwoya district, prefer a landrace variety Ajuko Manyige, because of its early maturity, high yields, and consumer traits like ease of grinding, and flavorful bread production. Similarly, in Lira district, farmers exhibited preferences, for the landrace variety Kal Atar due to its attributes like early maturity, moderate yields, and marketability suitable for both food and local brew, while Okello Chiba stood out for its visual appeal, tallness, sensory qualities making it ideal for local brewing (Wanyera, 2005; Owere et al., 2014).

In terms of gender, more men compared to women prefer high yielding varieties, and this is consistent with the finding by Nchanji et al. (2021) who reported that men tend to adopt and grow better yielding improved varieties while women tend to grow landraces with low yields. This difference in preferences highlights the diverse roles and responsibilities of men and women in agriculture, influencing their distinct criteria for selecting finger millet varieties (Tufan et al., 2018; Weltzien et al., 2019; Sanya et al., 2020, 2023; Marimo et al., 2021; Zimba et al., 2023). Although there was no significant difference in other traits considered during the production of finger millet, it's evident that similar traits are prioritized differently by men and women. In this study, both men and women prioritized early maturity as the most important trait. This could be due to advantages associated with this trait such as rapid maturation, timely harvesting, drought escape, and reducing post-harvest labor demands (Owere et al., 2014; Kasule et al., 2023). In addition, women also prioritized drought tolerance, followed by taste, high yield, and big head while men prefer early maturity, high yield, drought tolerance, test, and big head. This is consistent with earlier reports that women tend to focus more on food security-related traits as well as productivity under sub-optimal soil fertility (Christinck and Kaufmann, 2017) while men tend to focus on overall increase in farm productivity and income generation (Zimba et al., 2023).

Earlier studies have indicated that women tend to focus more on food preparation traits than men (Weltzien et al., 2019; Frimpong et al., 2023). Our finding contradicts this where more men indicated a preference for finger millet with good cooking quality. Discussion with key informants indicated that finger millet is highly valuable food among millet communities with deep cultural rooting for example when a boy marries a woman, the potential of that woman as a good wife is tested by the quality of the first millet bread she will serve the father in-law. Finger millet is used to perform many cultural functions of which men are the leaders of such function and therefore they put keen interest on the quality of the final product which in most cases is the millet bread. However, there were no significant gender differences for traits like short cooking time, stickiness, use of little flour to mingle, nice aroma, and makes a good color when mixed with cassava. This suggests shared values related to convenience, visual appeal, and sensory experiences among female and male consumers and the universal importance of certain sensory and cooking attributes. Overall, it's crucial to acknowledge that these gender-specific preferences are likely influenced by socio-cultural factors, household dynamics, and women's roles in agricultural decision-making (Quisumbing et al., 2014). The observed variations underscore the importance of integrating gender-sensitive approaches in breeding programs and extension services, ensuring that new finger millet improved varieties meet the needs of both female and male farmers and consumers, promoting sustainable and inclusive agriculture.

4.4 Socio-demographic factors that influence finger millet preferences in Uganda

Principal component analysis (PCA) offered a comprehensive understanding of major attributes that guide the decision-making process of finger millet farmers in Uganda. Farmers appeared to weigh in on agronomic (high yields, drought tolerance, pest tolerance, big millet heads, big grain size, plant height, and disease resistance), market-oriented (high market demand), and sensory (taste) traits. Farmer preferential traits from this study are in agreement with reports obtained by Otieno et al. (2021), Kasule et al. (2023), Singh and Vemireddy (2023), who reported similar attributes. Therefore, the Finger Millet Breeding Program in Uganda should not only breed varieties with good agronomic traits but also with sensory and market-oriented traits. Kasule et al. (2020), also reported that farmer varietal adoption and uptake of improved varieties is beyond agronomic and resistance traits in Uganda. Ensuring a balanced set of agronomic, market-oriented, and sensory traits would change farmers' minds from cultivating landraces to improved varieties.

Probit model results revealed that gender, marital status, education levels, and occupation are the major socio-demographic factors that influence specific preferences related to the cultivation of finger millet. Gender-related differences in preferences arise from the different roles and responsibilities within households (Sanya et al., 2023; Zimba et al., 2023). Female farmers prioritized millet varieties with big grain size, taste, and ease of cultivation, differently from their male counterparts who prefer varieties that are high yielding, and drought tolerant. These findings align with previous research which emphasized the importance of recognizing and addressing gender-specific needs in finger millet and other crops (Weltzien et al., 2019; Marimo et al., 2021; Otieno et al., 2021; Frimpong et al., 2023; Zimba et al., 2023).

Marital status is also an important factor in shaping preferences among finger millet farmers in Uganda. Similar results were reported by Acevedo et al. (2020), Andiku et al. (2021), in other cereals. Higher odds associated with high-yielding varieties among married farmers suggest influences related to household dynamics, joint decision-making, or differing priorities based on family structure. Extension workers in Uganda ought to understand household dynamics and marital status to improve finger millet adoption in Uganda. Education levels influence the adoption of finger millet varieties with high market demand, high yields, taste, big heads, and size. Education drives access to information, and awareness of modern agricultural practices, technologies, and improved varieties (Andiku et al., 2021; Mireri et al., 2023). Other researchers also attributed education to influencing finger millet farmers' decision-making (Mbinda et al., 2021; Mireri et al., 2023). Furthermore, the main occupation particularly where a farmer is engaged in crop farming influences the adoption of finger millet that is drought tolerant (Table 9). Farmers actively involved in farming are aware of specific needs and challenges faced while cultivating finger millet like drought and therefore, opt for climate-resilient varieties (Choudhary et al., 2023; Zimba et al., 2023). In addition, age also influences varietal adoption with older farmers less likely to choose disease-resistant finger millet compared to younger farmers. Hence addressing age-related differences is also pivotal in designing interventions that cut across different age groups.

5 Conclusions and recommendations

The information obtained from this study provides valuable insights into the importance of finger millet in Uganda. There is a surge in finger millet cultivation influenced by factors like land access and ownership, age, gender dynamics, and socio-cultural practices. The study also underscores the significance of women in finger millet production. However, despite the potential benefits of improved finger millet varieties, the adoption rate is still very low. Farmers have a preference for traits of finger millet landraces, indicating a need for the breeding program to align with farmer preferences. The observed differences between men and women in terms of their preferences for finger millet traits call for a more gender-responsive and demand-driven finger millet breeding system. The finger millet seed system in the country is also mainly informal with the majority of the farmers using home-saved seeds they recycle from one generation to another. Integrating actors in the seed system chain within the breeding process is likely to create interest and open opportunities for formal millet seed system development thereby ensuring that the improved varieties reach the diverse end-users.

Most finger millet farmers in the western and northern regions of Uganda are women with limited access to improved technology and low levels of education. Therefore, an innovative approach to technology transfers especially through farmer field schools where farmers learn by seeing and doing needs to be emphasized in promoting improved finger millet varieties to such farmers. In addition, labor-saving machineries need to be customized and promoted to address drudgery along the finger millet value chain to encourage more women, men, and youth to engage in production, thereby ensuring sustainable food, nutrition, and income security among smallholder farmers.

Farmers take into consideration agronomic, sensory, and cooking traits like early maturity, high yields, drought tolerance, taste, and good cooking quality among others while selecting finger millet varieties. However, in this study, limited information was obtained concerning sensory traits and cooking characteristics of finger millet. There is a need to conduct extensive processing and acceptability studies (consumer studies) to explore and discover the sensory traits and cooking quality characteristics that influence end-user selection of finger millet varieties. The study also revealed gender-based differences in trait preferences, emphasizing the need for gender-inclusive finger millet breeding in Uganda. Socio-demographic factors including gender, marital status, education levels, and main occupation influence farmer preference for finger millet varieties. Recognizing and accommodating these factors is crucial for promoting the adoption of improved varieties. This study lays the foundation for informed interventions, emphasizing the necessity of a comprehensive approach to further promote finger millet cultivation in Uganda.

6 Policy implications

Moving forward, this study provide insight for crop improvement teams to define and refine customer-oriented and market-driven product profiles for finger millet breeding programs. Robust efforts are necessary to design a holistic strategy and effective campaign for reaching out to farmers and end users to popularize the available released finger millet varieties and their traits to enhance adoption. Small seed pack models, seed fares, massive radio campaigns, and strengthened partnerships in the agricultural sector are part of the proposed approaches. Challenges of poor seed systems for finger millet could be addressed using the Local Seed Business (LSBs) approach to ensure that seeds are made available in the different communities.

Data availability statement

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

Ethics statement

Ethical approval was not required for the studies involving humans because this research was authorized by the National Agricultural Research Organization (NARO) which by its mandate follows scientific and ethical processes while conducting research. Informed consent was obtained from all the participants involved in the study and they provided their written informed consent to participate in this study. 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

SH: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. FK: Bibliography, Data curation, Formal analysis, Visualization, Software, Writing – review & editing. IM: Data curation, Writing – review & editing. MB: Supervision, Writing – review & editing. HN: Conceptualization, Writing – review & editing. LS: Conceptualization, Methodology, Validation, Writing – review & editing. DR: Conceptualization, Data curation, Methodology, Supervision, Validation, Visualization, Writing – review & editing. MO: Conceptualization, Data curation, Methodology, Supervision, Validation, Visualization, Writing – review & editing. SA: Funding acquisition, Project administration, Resources, Supervision, Writing – review & editing.

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Conflict of interest

DR was employed by Cultural Practice, LLC.

The remaining 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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