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Farmers' preferences for East African highland cooking banana 'Matooke' hybrids and local cultivars

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Abstract

Background An understanding of farmers' preferences of new banana cultivars and their characteristics is critical for developing and selecting cultivars that meet consumer needs. Therefore, phenotypic selection in a genetically variable population remains an important aspect of plant breeding.

Methods The participatory varietal selection approach for preference ranking was used on 31 'Matooke' secondary and primary triploid hybrids and local banana cultivars evaluated between 2016 and 2019 in Uganda and Tanzania to investigate how farmers' preference attributes could help breeders identify superior cultivars. The quantitative data were analyzed using the Statistical Package for Social Sciences (SPSS). The qualitative data from farmers' focus group discussions (FGDs) were described using content analysis. The Mann–Whitney U test and Wilcoxon's signed-rank test were used to confirm the difference in farmers' preferences between groups.

Results Farmers' approaches for defining characteristics were multivariate, and their preferences varied by site and country. Large fruit, a large bunch, market acceptability of the banana bunch, a sturdy stem, and an attractive appearance of the banana plant were the characteristics most preferred by farmers in Tanzania and Uganda. Tanzanian farmers preferred large bunches over other characteristics like bunch marketability and robust stem. Large fruit, drought tolerance, a strong stem, and phenotypic similarity to local cultivars were prioritized by Ugandan farmers. Both men and women farmers were more concerned with production-related characteristics, but the former valued marketing-related characteristics more, while the latter preferred use-related characteristics. Their preferences did not differ statistically, but the relative importance assigned by each group to the selected attributes was different.

Conclusion Farmers' varietal preferences are frequently based on some assumed requirements, resulting in cultivar rejection or non-adoption. Therefore, determining the value attributed to each characteristic by various farmer groups is crucial in developing 'Matooke' banana cultivars with desired attributes that will boost the rate of adoption on-farms. Breeding initiatives that establish a system of integrated approaches and rely on thorough diagnosis of both production and consumption characteristics will best serve farmers' diverse preferences. To accomplish this, planning

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for varietal improvement initiatives at various levels—including internationally, regionally, nationally, and locally—would require a strong participatory structure that is gender inclusive.

Keywords Farmers' characteristic preferences, Participatory varietal selection, 'Matooke' banana cultivars

Introduction

Despite advancements in genetics and the use of molecular technology in agricultural research, crop breeding is still primarily based on field-based yield expression and a small number of agronomically important characteristics for cultivar selection [1]. Farmers' first impression of banana cultivars, as well as their desire to test them in their fields, is influenced by characteristics such as plant stature, stem vigor, bunch size, among others. They are also important indicators of a product's commercial value and a critical motivator for initial purchase [2]. As a result, phenotypic selection in a genetically variable population remains an important aspect of plant breeding [3]. It leads to adaptation in the local environment after selecting repeatedly for the target characteristics across growing seasons if the source breeding germplasm had genetic variability for it, particularly for a characteristic significantly influenced by the environment such as edible yield [3]. Accurate phenotypic assessment also allows for data dissection based on genotypic and environmental variables [4], assisting plant breeding in the development of novel cultivars [5].

Bananas are one of the most important staple crops in East Africa (EA), providing food security as well as a source of income for millions of smallholder farmers [6]. Banana consumption per capita in East and Central Africa (ECA) is 147 kcal per day, which is 15 times higher than the global average and six times higher than the African average. Uganda and Tanzania produce most of the bananas harvest in the region with a combined annual output of 20.4 million tonnes [7–10]. The primary constraint in rural resource-poor communities in ECA has been a low rate of adoption of improved banana cultivars, which resulted in unchanged low yield and income. A few farmers in the ECA grow improved banana cultivars, with adoption rates in Uganda and Tanzania being very low [11]. One of the most significant barriers to adoption has been a failure to place enough emphasis on farmers' preferences and perceptions in varietal selection and genetic improvement of the crop [12, 13], as well as a lack of available functional seed systems and a limited number of alternative improved cultivars.

Farmers' production priorities are frequently misunderstood as being centered on yield maximization and financial returns, despite the fact that they extend far beyond factual concepts of production efficiency and nutritional value [14, 15]. Farmers typically use complex criteria to evaluate new cultivars based on their various farming objectives. Crossbreeding generally seeks cultivars with high yield, early maturity, host plant resistance to pests and pathogens, and good taste. Farmers, on the other hand, consider a number of other factors in their adoption decisions, which can be different from those of breeding programs [16–19]. According to Cleveland et al. [20], farmers' selection criteria vary depending on environmental conditions, characteristics of interest, ease of cultural practice, crop processing, use, and marketability, and ceremonial and religious values. Furthermore, high environmental variability, according to Danial et al. [21], leads to heterogeneity in farmers' preferences and limits the success of breeding programs. Farmers' cultivar preferences varied not only across locations but also across seasons [22]. While most breeding efforts have focused on a good season, when rainfall is plentiful, most farmers grow bananas in an uncertain environment that is primarily influenced by climate change.

Subsistence farmers, who make up most of the rural farming populations in the developing world, frequently place a higher value on banana cultivars' social and cultural aspects than on their agronomic performance. Gender-specific needs and priorities also influence differences in characteristic preferences [23]. According to Christinck et al. [24], men prioritize production-related qualities, whereas women prioritize culinary and postharvest aspects. Because of the complexity involved in developing acceptable cultivars for variable marginal environments, breeders must develop a thorough understanding of men and women farmers' needs and preferences, as well as the ability to prioritize these characteristics based on socioeconomic and environmental conditions [25].

Participatory varietal selection (PVS) procedures are routinely used to aid in the identification of the characteristics that farmers value in cultivars from the breeding program [26], as well as to facilitate their adoption and dissemination, all of which result in positive outcomes. Farmers' criteria and preferred quality, according to Thapa et al. [27], can be integrated into the breeding program by using overall preference scores when selecting cultivars, because these overall scores take into account and balance out the effects of all relevant characteristics. Bellon [28] emphasizes the importance of a breeding program that considers "subjective" characteristics, or those that are essentially a "product of human perception".

Recent advances in *Musa* spp. crossbreeding have demonstrated hybridization's potential in the development of new banana cultivars [29]. The genetic basis for hybrid selection and phenotypic evaluation in this study were a secondary and primary triploid East African Highland Banana (EAHB) (hereafter referred to as 'NARITA') hybrids derived from two interploidy crossing blocks [30]. This is the result of more than two decades of joint breeding efforts by Uganda's National Agriculture Research Organization (NARO) and the International Institute of Tropical Agriculture (IITA). The use of local cultivars in crossing programs is one approach to address the challenge of developing farmer-appealing adapted cultivars, while also contributing to the sustainable use of local crop genetic resources.

IITA and NARO tested NARITA hybrids in Uganda, for edible yield and cropping cycles, as well as durability of host plant resistance to *Pseudocercospora fijiensis* [30], which is the pathogen causing black leaf streak, previously known as black Sigatoka [31]. Subsequently, multi-locational trials for participatory varietal selection were established in Tanzania and Uganda with the goal of selecting clones that combine host plant resistance to black leaf streak with stable high yield and other desirable quality characteristics, and to assess their adoption potential with farmers and consumers vis-à-vis their parental landraces and exotic cooking bananas. Despite the fact that several empirical studies have been conducted to identify farmers' preferred characteristics, few studies have specifically considered understanding the visual attributes of novel EAHB hybrids, particularly using farmers' preference scores. The majority of available studies have primarily focused on early-stage (ex ante) adoption of these cultivars to explain the likelihood of farmers' adoption and consumers' willingness to purchase the 'Matooke' hybrids, as well as sensory attributes assessment [32–34]. This study therefore attempts to investigates the relative importance of characteristics used by farmers in Uganda and Tanzania to select improved 'Matooke' banana cultivars with the target of informing breeding initiatives in East Africa. The study specifically evaluated whether farmers in Uganda and Tanzania seek

Table 1 Code, name, and origin of the genotypes tested in Tanzania and Uganda

Genotype code[y]	Genotype	Origin	Use	Type
N2	NARITA 2	IITA/NARO[z]	Food	Hybrid
N4	NARITA 4	IITA/NARO	Food	Hybrid
N6	NARITA 6	IITA/NARO	Food	Hybrid
N7	NARITA 7	IITA/NARO	Food	Hybrid
N8	NARITA 8	IITA/NARO	Juice	Hybrid
N9	NARITA 9	IITA/NARO	Juice	Hybrid
N10	NARITA 10	IITA/NARO	Juice	Hybrid
N11	NARITA 11	IITA/NARO	Food	Hybrid
N12	NARITA 12	IITA/NARO	Food	Hybrid
N13	NARITA 13	IITA/NARO	Juice	Hybrid
N14	NARITA 14	IITA/NARO	Food	Hybrid
N15	NARITA 15	IITA/NARO	Food	Hybrid
N16	NARITA 16	IITA/NARO	Juice	Hybrid
N17	NARITA 17	IITA/NARO	Food	Hybrid
N18	NARITA 18	IITA/NARO	Food	Hybrid
N19	NARITA 19	IITA/NARO	Food	Hybrid
N20	NARITA 20	IITA/NARO	Food	Hybrid
N21	NARITA 21	IITA/NARO	Juice	Hybrid
N22	NARITA 22	IITA/NARO	Food	Hybrid
N23	NARITA 23	IITA/NARO	Food	Hybrid
N24	NARITA 24	IITA/NARO	Food	Hybrid
N25	NARITA 25	IITA/NARO	Food	Hybrid
N26	NARITA 26	IITA/NARO	Food	Hybrid
N27	NARITA 27	IITA/NARO	Food	Hybrid
Mbwaz[u]	'Mbwazirume'	Farmer selection	Food	Local cultivar
Kisa[x]	'Kisansa'	Farmer selection	Food	Local cultivar
Nak[x]	'Nakitembe'	Farmer selection	Food	Local cultivar
Nsha[x]	'Nshakala'	Farmer selection	Food	Local cultivar
NdizUg[x]	'Ndizi Uganda'	Farmer selection	Food	Local cultivar
Eny[x]	'Enyoya'	Farmer selection	Food	Local cultivar
NdizNg[x]	'Ndizi Ng'ombe'	Farmer selection	Food	Local cultivar

[u] Mbwazirume': standard local cultivar planted in the five sites

[x] Site-specific local cultivars: 'Kisansa' and 'Nakitembe' planted in Kawanda and Mbarara; 'Ndizi Uganda' planted in Lyamungo and Mitalula; 'Ndizi Ng'ombe' planted in Lyamungo, and 'Enyoya' and 'Nshakala' planted in Maruku

[y] Codes used in the text

[z] IITA, International Institute of Tropical Agriculture; NARO, National Agriculture Research Organization (in Uganda)

any specific preferred characteristics for improved banana cultivars, and if there were differences in cultivars and characteristic preferences between men and women farmers. This knowledge will assist banana breeders in prioritizing and focusing research, resulting in increased rates of on-farm adoption among men and women farmers.

Methods

Twenty-four 'Matooke' secondary and primary triploid hybrids 'NARITAs' (N) and seven 'Matooke' triploid local cultivars were evaluated in three sites in Tanzania and two sites in Uganda, from 2016 to 2019 (Table 1). The locations of the multi-site trials were chosen to represent the major banana-growing agro-ecozones in Uganda and Tanzania, and the trials were set up with farmers' input levels across a wide range of land types and management regimes, ensuring that the results are representative of the test villages and likely to be representative of the target environments in general. In addition to physical environments, food security issues such as low crop yields, were given careful consideration. Tanzanian evaluation sites were at the sub-research centers of Tanzania Agricultural Research Institute (TARI) in Mitalula for TARI-Uyole, Maruku for TARI-Ukiriguru, and Horti-Tengeru for TARI-Selian, which leased the field from Tanzania Coffee Research Institute (TaCRI) and later became known as the Lyamungo site. The two Ugandan sites, Kawanda and Mbarara, were established at the NARO sub-centers of Kawanda Agriculture Research Institute in Uganda's central region and the Mbarara Zonal Agricultural Research and Development Institute in Uganda's western region, respectively. The sites differed in elevation, soil type, and rainfall patterns (Table 2).

The genotypes were planted in four replicates of 12 plants plot^{-1} using a randomized complete block design (RCBD). The plantings in Tanzania and Uganda were in April and May 2016, respectively. Site-specific farmers' landraces, as well as a standard local cultivar check and the widely grown local cultivar 'Mbwazirume' were planted alongside the hybrids. The local cultivar checks chosen are a fair representation of what farmers are currently growing. The plants (2- to 3-month-old tissue culture) were spaced 3 m apart, yielding a plant density of 1152 plants ha^{-1}. The planting hole was 100 cm in diameter. Some plants died after planting due to a range of factors, including drought, and were replaced with suckers from surviving mats of the same cultivar in the trial. Three plants, representing different cycles, were kept per mat as management practices to limit competition for food and water. The farmyard manure was applied at a rate of 10 kg hole^{-1} prior to planting. Every two to 3 months, weeding was performed. On a regular basis, dead leaves were removed. Mulching was done at the beginning of each dry season in the two Ugandan sites and in Maruku, while furrow and basket irrigation were used in Lyamungo and Mitalula sites, respectively. Staking was done to maintain the fruiting plants upright. Other trial management approaches were aligned with appropriate crop husbandry procedures used by farmers in the specific areas.

Theoretical framework

The agricultural household model makes it possible to test theories regarding the relationship between a household's selection of cultivars and characteristics unique to those cultivars. The model suggest that a farmer's decisions to embrace a new technology during a specific time period result from maximizing predicted utility while taking input limits into consideration [35]. Lancaster [36] stated that products are as good as their desirable and undesirable characteristics, and the qualities incorporated within give rise to utility, in what is now known as the characteristics theory of consumer choice. The utility that farm households derive from the characteristics of the hybrid banana plants is what drives farmers' demand. Consider a farmer's selection of a cultivar, and assume that utility is determined by the selection from a set (C), that is, the set that includes all possible cultivar alternatives. A farmer selects a banana cultivar with the best combination of characteristics for his

Table 2 Description of agro-climatic characteristics of testing sites in Tanzania and Uganda

Site	Country	Global position		Altitude (m)	Rainfall (mm·year^{-1})	[x]Temperature (°C)			Soil type
		Latitude	Longitude			Min	Max	Avg	
Kawanda	Uganda	0°24′ 53.39"N	32°31′ 56.57"E	1210	1190	16	29	23	Sandy Clay Loam
Mbarara	Uganda	0°36′ 1.16"S	30°35′ 54.35"E	1430	1219	14	31	23	Sandy loam
Maruku	Tanzania	1°25′ 28.05"S	31°46′ 24.91"E	1300	2000	16	30	23	Sand/silt loam
Mitalula	Tanzania	9°23′ 51.69"S	33°37′ 39.14"E	1517	2200	16	25	21	Clay loam
Lyamungo	Tanzania	3°13′ 48.27"S	37°14′ 54.40"E	1270	2389	14	27	21	Loam

Max minimum, *Min* minimum, *Avg* average

[x] Annual temperature

or her utility. As a result, farmers derive utility (U) from the banana cultivar's characteristics (z):

$$U_{ij} = U_{ij}(z_1, z_2, \ldots, z_m),$$

where $z_i = a_{ij}q_j$ is the amount of ith characteristic obtained by selecting the jth cultivar, a_{ij} is the amount of ith characteristic per unit of the jth cultivar, and q_j is the quantity of j th cultivar selected ($i = 1, \ldots, m$ and $j = 1, \ldots, n$).

The farmer's choice of selecting hybrids versus local banana cultivars is then analyzed within the random utility discrete choice model [37]. The utility function is assumed to be known by the individual but some of its components are unobserved by the researcher. This unobserved part of the utility is treated as a random variable. Then, the utility for the hybrids banana cultivar choice is modeled as the sum of the observed characteristics and not the observable random component (ε_{io}):

$$U_{io} = \beta'_{io}z_i + \varepsilon_{io}.$$

In the same way, the local banana cultivar choice utility is defined as:

$$U_{ic} = \beta'_{ic}z_i + \varepsilon_{ic},$$

where β'_{io} and β'_{ic} are vectors of parameters to be estimated. The utility derived from any alternative cultivar is determined by the cultivars characteristics (z) as well as other socioeconomic and agro-ecological factors influencing farmers' decisions. Choices between alternatives will be based on the likelihood that the utility associated with a specific option is greater than that associated with other alternatives. That is the hybrid banana cultivars will be chosen if $U_{io} > U_{ic}$. The probability that the farmer chooses the hybrids cultivar is given by:

$$P(y_o) = P(U_{io} > U_{ic}) = P(\varepsilon_{ic} - \varepsilon_{io} < \beta'_{io}z_i - \beta'_{ic}z_i),$$

where y_o is a binary choice variable for the hybrid banana cultivars, U_{io} and U_{ic} are the conditional indirect utility functions and o and c subscripts represent hybrids and local banana cultivars, respectively. Assuming a cumulative normal distribution and defining $\varepsilon_i = \varepsilon_{ic} - \varepsilon_{io}$ and $\beta'_i = \beta'_{io}z_i - \beta'_{ic}z_i$, the bivariate choice model can be represented in terms of a latent variable model:

$$y_i^* = \beta'_i z_i + \varepsilon_i \varepsilon_i \approx N(0, 1),$$

where y_i^* is an unobservable latent variable denoting the probability to choose hybrid banana cultivars. The related observable variable y_i is defined as follows:

$$\begin{array}{ll} y_i = 1 & \text{if } y_i^* \geq 0 \text{ or } \varepsilon_i \geq -\beta'_i z_i \;\; U_{io} > U_{ic} \\ y_i = 0 & \qquad\qquad\qquad\qquad \text{Otherwise} \end{array}.$$

Farmers' demand for various cultivar characteristics also influences their cultivar selection [38]. Farmers typically choose cultivars based on bundles of observable characteristics that each variety embodies and produces [39–41]. Farmers' desire for cultivar characteristics, in turn, drives crop cultivar adoption [38]. If these cultivars do not provide the attributes that farmers want, such as the production and consumption characteristics, farmers are less likely to prefer them [39]. In this study, we suppose that a farmer has an option between many hybrid and local banana cultivars. In a choice situation, the individual farmer is assumed to assess the entire set of given alternative hybrid bananas and local cultivars and must select the alternative that maximizes utility [42]. New hybrid banana cultivars have distinguishing characteristics that set them apart from one another and from local cultivars, such as plant vigour, bunch size, finger size and shape, pest and pathogen tolerance, taste, flavor, food color and visual appearances. Both unobservable and observable characteristics distinguish hybrid bananas from conventional bananas. Therefore, preference is contingent on the existence of a bundle of desired attributes conferred by a given cultivar (as perceived by the farmer). The desired attributes may include only consumption characteristics (such as taste and color), only production characteristics (such as yield and disease resistance), or both (e.g., taste and yield) [43]. As a result, the extrinsic characteristics of the cultivar may be important determinants of the adoption decision. Ranking or rating techniques can be used to obtain information from households that grow bananas about the relative importance of characteristics and the degree to which farmers believe that certain cultivars of bananas provide those characteristics. The adoption of improved cultivars with one or more genetic traits (attributes) can then be predicted using responses, while controlling for other important physical and economic factors [44].

Preference analysis

A group of 80 to 120 farmers visited the trial sites in 2018 for a field day to visually evaluate the most desirable cultivars, which were then categorized on a quantitative scale to find the best ones based on the preference analysis score (Additional file 1: Fig. S1). There were 34 men and 44 women in Maruku, 88 men and 43 women in Mitalula, 51 men and 51 women in Lyamungo, 21 men and 79 women in Kawanda, and 62 men and 54 women in Mbarara. Farmers from the neighboring villages joined the group of farmers, in addition to local village farmers. Mobilization was done 3 weeks before each exercise at each site with activities such as identifying and listing banana-growing households comprising both genders and ages ranging from the elderly to the young, who willingly agreed to engage in the preference ranking exercise. This was accomplished with the assistance of district officials, extension staff, and village leaders. Each site was encouraged to have 120 farmers to participate. The village leaders reminded all selected participant farmers about the exercise one day before the event, which led to an increase in the number of farmers in participation.

The preference analysis (PA) was conducted during the pre-harvest period (Additional file 1: Table S1), when the majority of cultivars had reached about 80% physiological maturity [25]. Because banana is a perennial crop that produces bunches during the entire year, the investigation was carried out during the peak season (from July to October 2018), when mother plants with advanced agronomic growth and a large range of plants with matured bunches were available. This exercise allowed men and women farmers to vote on their "most- and least-preferred" cultivars. Farmers were initially asked to walk around the field in groups, observe coded-labeled genotypes, and classify the desirable visual characteristics for each cultivar, such as bunch size, fruit size, leaves, stem, pathogen resistance, plant height, suckering potential, and overall plant appearance, with the assistance of a researcher. Farmers were also allowed to discuss with other farmers the appearance of cultivars and what characteristics they liked or disliked.

They were also allowed to ask the researchers for clarification on characteristics they could not see but were interested in, such as maturation period, or chop and peel a banana fruit to rate the pulp and sap color and peeling difficulty. Farmers were then given three types of voting ballots ('liked,' 'do not like,' and 'do not know'), each with the same number of cultivars to be voted on. They were asked to cast one vote for each cultivar, by depositing their ballots in a bag or envelope placed in front of each cultivar. To highlight any gender differences in varietal preferences, men and women farmers cast distinct colored votes [25, 45].

For each cultivar, the preference score (PS) was calculated by adding the number of 'liked' ballots (weight = 1), 'do not know' ballots (weight = 0.5), and 'do not like' ballots (weight = 0), multiplying by 100, and dividing by the total number of 'liked,' 'do not know,' and 'do not like' ballots. The PS is a number between 0 and 100 that indicates how much the concerned cultivar was liked by the group of respondents (0—no one liked it; 100—everyone liked it). To quickly enter the votes of the participant farmers and calculate the PS for each cultivar, disaggregated by gender, a pre-formatted excel sheet was used [25, 45]:

$$\text{PS}\ (\%) = \frac{[(n_1 * 1) + (n_2 * 0.5) + (n_3 * 0)] * 100}{(n1 + n2 + n3)}.$$

With n_1 = the number of 'like' ballots, n_2 = the number of'do not know' ballots, n_3 = the number of'do not like' ballots.

The results of the PS computation were presented to the farmers for discussion of their reasons for the most- and least-preferred cultivars. The participants were given the names of the three most preferred and three least-preferred cultivars for each gender. The group was then divided by gender, and participants discussed the characteristics they liked in the three most preferred cultivars and disliked in the three least-preferred cultivars. The participants returned to the field to observe the characteristics of the cultivars selected. The discussions were facilitated by enumerators, and a note taker jotted down observations on flipcharts. The participants, who had been separated into two groups—one for men and one for women—then listed—in order of importance—the most important criteria they considered when selecting a new banana cultivar. They also gave a brief explanation for each. The PA usually produced two sorts of data in the end: (a) a quantitative preference score for each cultivar, and (b) a list of characteristics that farmers liked about the preferred cultivars.

Data analysis

The analysis tools used were both qualitative and quantitative. The Statistical Package for Social Science (SPSS) [46] was used to analyze the quantitative data. The qualitative data from farmers' focus group discussions (FGDs) were described using content analysis. The Mann–Whitney U test was used to verify the difference in farmers' preference between local and hybrid cultivars at each location, based on the preference scores derived by each farmer's positive or negative votes allotted to each cultivar. Wilcoxon's signed-rank test was also used to see if gender influenced cultivar preferences. Furthermore, the Spearman's rank correlation was used to analyze the association between men and women farmers' cultivar preference scores for selection criteria.

Results and discussion

Farmers' cultivar preferences

Farmers were asked to vote on their most and least-preferred cultivars during the PA, resulting in a ranking of all hybrids and cultivars based on farmer preference scores. Farmers preferred the local cultivars 'Enyoya' (PS = 95), 'Nshakala' (PS = 93), 'Mbwazirume' (PS = 77), 'Nakitembe' (PS = 76), and 'Kisansa' (PS = 70). Other local cultivars that scored lower were 'Ndizi Ng'ombe' (PS = 52) and 'Ndizi Uganda' (PS = 34) (Tables 3 and 4). The NARITA hybrids with PS values that were very close to the best local cultivars were N2 and N23, which tied for

Table 3 Farmers' most and least preferred cultivars according to their preference score (PS) rank, as well as their characteristics for selection across Tanzania and Uganda

Most-preferred cultivars			Least-preferred cultivars		
Cultivars	PS	Characteristics	Cultivars	PS	Characteristics
'Enyoya', 'Nshakala', 'Mbwazirume', 'Nakitembe', 'Kisansa'	1	• Large bunch •Bunch marketability • Large fruit • Vigorous stem • Appealing plant appearance • Tolerant to drought • Less affected by diseases • High cultural value and respect, for wedding ceremonies • Can withstand wind • Leaves and stem for animal feed • Has fibers that can be used as rope to tie grass, for thatching, making poaches, hut caps	NARITA 17	1	• Small fruit • Short fruit • Unappealing bunch appearance • Unappealing plant appearance • Inability to retain leaves during the dry season • Unhealthy suckers • Resembles a juice banana cultivar
NARITA 2 and NARITA 23	2	• Large bunch • Bunch marketability • Compact bunch • Vigorous stem • Appealing plant appearance • Tolerant to drought • Not affected by diseases • Retain many leaves • High sucker ability • Resembles local cultivar 'Bogoya'	NARITA 19 and NARITA 20	2	• Small bunch • Small fruit • Not suitable for business • Unhealthy and thin pseudostem • Unappealing plant appearance • Unable to withstand drought, leaves are drying • Difficult to peel
NARITA 4 and NARITA 12	3	• Large bunch • Bunch marketability • Large fruit • Many fruit • Not affected by diseases • Tolerant to drought • Many healthy suckers • Resembles local cultivars 'Enjagata' and 'Ndizi Bukoba' • Medium plant stature	NARITA 10	3	• Small bunch • Not suitable for business • Small compact fruit despite maturation • Fruits are short • Weak stem • Unappealing plant appearance • Not tolerant to drought • Resembles a juice cultivar due to very dark pseudostem

the PS scores (75). N4 and N12 also tied for the PS scores (68) and were ranked among the top 10 most preferred cultivars (Table 3 and Table 4). N23 is a food type with a high bunch weight (30 kg) across all the five sites, while N2 is another food type that performed reasonably well across sites (22 kg). 'Mbwazirume' is a local food type cultivar with an intermediate bunch weight (18 kg) across all sites. Other top-ranked local cultivars performed poorly in terms of yield across sites, with a bunch weight below 18 kg.

Cultivars were chosen for a range of reasons, including large bunch size and associated characteristics such as bunch marketability, medium plant stature, pathogen resistance, consumption, and animal feed attributes. There was also mention of characteristics associated with banana plant leaves and pseudostem vigor (Table 3). Farmers consider that a vigorous pseudostem and numerous leaves indicate a healthy plant that will produce a high yield, whereas the cultivar's ability to withstand environmental shocks while producing a consistent yield is thought to be linked to host plant resistance to pathogens(s). Thus acceptance of a cultivar is influenced by various factors [26, 47–49]. Farmers typically combine information from different attributes to assign a value to a cultivar. Although yield is not always the only criterion for adoption, it is widely regarded as one of the most important. As a result, evaluating the value of each quality assigned by farmers is critical in developing cultivars

Table 4 Preference scores (green: high; yellow: moderate; red: low) heatmap disaggregated by gender for banana cultivars after multi-site trials at Mbarara, Kawanda Maruku, Mitalula, and Lyamungo

Genotype	Use type	Kawanda			Mbarara			Maruku			Mitalula			Lyamungo			Average across sites			Mean Bunch weight (kg)
		Preference score			Preference score			Preference score			Preference score			Preference score			Preference score			
		Men	Women	Total	Men	Women	Total	Men	Women	Total	Men	Women	Total	Men	Women	Total	Men	Women	Total	
NARITA 2	Food	70	70	70	92	81	87	57	60	59	84	68	79	79	71	75	76	72	75	22
NARITA 4	Food	60	79	76	94	85	90	39	46	43	70	54	65	88	73	81	70	65	68	25
NARITA 6	Food	28	28	28	56	57	57				40	37	39	86	79	82	52	50	51	19
NARITA 7	Food	85	77	79	23	30	27	78	83	81	30	62	44	51	51	51	53	61	57	24
NARITA 8	Juice	79	72	73	28	32	30	43	37	40	84	69	79	38	34	36	54	49	52	23
NARITA 9	Juice										43	43	43	92	85	88	68	64	66	18
NARITA 10	Juice	50	55	54	26	28	27	44	32	37	57	58	57	23	30	27	40	39	39	22
NARITA 11	Food	55	68	66	31	27	29	71	73	72	86	79	83	90	86	88	67	65	66	21
NARITA 12	Food	65	82	78	48	54	51	89	84	86	81	63	75	59	77	68	68	67	68	25
NARITA 13	Juice	34	34	34	66	67	66	57	59	58	61	44	56	66	55	61	57	52	55	23
NARITA 14	Food	50	46	46	28	37	32	50	53	52	36	25	32	42	50	46	41	41	42	17
NARITA 15	Food	85	80	81	68	75	71	58	48	52	22	24	23	71	81	76	61	61	61	13
NARITA 16	Juice	60	76	73	24	35	29										42	42	42	14
NARITA 17	Food	26	27	27	20	25	22										23	26	25	29
NARITA 18	Food	73	66	68	49	58	53				31	35	32	62	60	61	54	54	54	27
NARITA 19	Food							38	33	35	31	43	35	40	52	46	36	43	39	10
NARITA 20	Food							36	31	33	54	34	48	20	27	24	37	31	35	20
NARITA 21	Juice	45	37	39	37	40	38	46	39	42	67	71	68	61	72	66	51	53	52	21
NARITA 22	Food							89	98	94	60	67	62	25	55	40	58	73	65	*
NARITA 23	Food	80	69	71	65	64	64	91	87	89	77	70	75	70	66	68	76	73	75	30
NARITA 24	Food	58	78	74	35	37	36										46	46	46	25
NARITA 25	Food	32	39	37							74	64	71	52	43	47	53	46	50	22
NARITA 26	Food							83	56	68	65	50	60	40	46	43	63	51	57	25
NARITA 27	Food							51	46	48	43	42	43	94	80	87	63	56	59	30
'Mbwazirume'	Food	88	92	91	64	63	64	93	97	95	49	58	52	84	93	88	75	80	77	18
'Nshakala'	Food							92	95	93							92	95	93	*
'Enyoya'	Food							95	96	95							95	96	95	18
'Ndizi Ng'ombe'	Food													43	61	52	43	61	52	*
'Ndizi Uganda'	Food										32	32	32	22	51	37	27	42	34	17
'Kisansa'	Food	65	69	68	75	77	76										70	70	70	16
'Nakitembe'	Food	93	92	92	60	59	60										76	76	76	16

* No reliable bunch weight due to poor number of standing plants

with desired quality that will increase the rate of on-farm adoption.

N17 was the least preferred of the 30 hybrids and cultivars tested (PS = 25), followed by the local cultivar 'Ndizi Uganda' (PS = 34) and the hybrids N20 (PS = 35), N19 (PS = 39), and N10 (PS = 39). The local cultivar 'Ndizi Uganda' produced a low yield across all sites (17 kg). N20 and N19 also produced few fruits across all sites, and N10 is a juice cultivar (Table 3). Farmers despised the N17 cultivar for its inability to retain leaves during the dry season, its small and short fruit, which traders and consumers dislike [41, 50], its unappealing appearance, and its unhealthy suckers for planting. In contrast, this cultivar performed exceptionally well in sensory testing and was ranked first in Uganda for sensory quality. These findings highlight the importance of integrating multiple selection criteria when recommending cultivars for release.

Farmers who tried to peel the cultivars' fruit reported that N20 and N19 hybrids were difficult to peel, had small bunch sizes with few fruits, were unsuitable for commercial use, and had a small pseudostem (Table 3). N10 was given a low score because of its unappealing overall appearance, short compact fruit despite maturation, and resemblance to a juice cultivar due to its excessively dark pseudostem. The wide range of farmers' perceptions of cultivar preferences shows the diversity of opinions within the banana farming community of different sites, as well as the factors that, if not considered during the breeding process, may be central to cultivar rejection. This discrepancy indicates that the variances are not random, but rather represent the preferences for specific farming segments within the communities where the testing sites were drawn. Given that cultivar preferences are tied to a variety of socioeconomic and production situations among farming households [24, 51], the inability to include these characteristics in banana cultivar development and selection processes is most likely to account for the region's poor adoption rate.

Individual site analysis revealed that farmers valued banana cultivars differently based on the plants' characteristics, which influenced their selection and local preferences. The local cultivars 'Nakitembe' and 'Mbwazirume' were the most preferred in Kawanda (Table 4). The most preferred hybrids were N15, N7, and N12, with PS that were quite similar to local checks. These food types produced low to high bunch weight across sites (13 kg, 24 kg, and 25 kg, respectively). Men ranked 'Nakitembe' first, 'Mbwazirume' second, and N15 and N7 tied for third place. Women ranked 'Mbwazirume' first, 'Nakitembe' second, and N12 third. Farmers liked the cultivars because they had large and long bunches and fruit, robust stems, healthy suckers, suitable leaves for animal feed, appeared pathogen-resistant, and had a pleasing plant appearance (Additional file 1:Table S2).

The hybrids N2, N4, and N13 were the most preferred cultivars in Mbarara. 'Kisansa' with preference scores near hybrids, was the most preferred local cultivar (Table 4). PS levels were also high in the hybrids N15, N13, and N23. N4 is a food type that produced 25 kg across sites, while N2 produced 22 kg. 'Kisansa' is a local food cultivar that was not tested in Tanzanian trials, but had the smallest bunch weight in Uganda. Men ranked N4 first, N2 second, and 'Kisansa' third. Women ranked N4 first, N2 second, and 'Kisansa' third. Reasons for farmers' preference are, a large bunch, a short plant that is not easily affected by wind, an attractive bunch appearance with nice fruit clusters that are well-spaced and numerous, a high suckering ability, ability to retain many leaves, and a drought-resistant appearance. (Additional file 1: Table S3).

'Mbwazirume', 'Nshakale', and 'Enyoya' were the most preferred local cultivars in Maruku (Table 4). These cultivars, on the other hand, had low bunch weight across sites (18 kg or below). The most desired hybrids in Maruku were N12, N22 and N23, with preference scores very near to the local cultivars. Across sites, these food types had high bunch yields (above 25 kg). Men ranked 'Enyoya' first, 'Mbwazirume' second, and 'Nshakala' third. Women ranked N22 and N23 first, 'Mbwazirume' second, and 'Enyoya' third. Farmers preferred the cultivars because they have a large bunch, many fruits, a high cultural value, market acceptance commanding a high price, and an appealing appearance (Additional file 1: Table S4).

The hybrids N2, N8 and N11, were the most preferred cultivars in Mitalula. They were chosen over the local cultivars 'Mbwazirume' and 'Ndizi Uganda' (Table 4). Men ranked N11 first, N8 second, and N2 third. Women ranked N11 first, N21 second, and N23 third. Farmers liked these cultivars for a variety of reasons, including their large fruit clusters and fruit appearance, robust stems and good plant stature, likeness to several local cultivars, and apparent pathogen resistance (Additional file 1: Table S5). N11 averaged 21 kg across all sites, while N2 averaged 22 kg. N8 produced well (23 kg) across testing sites, however, it is a juice cultivar. In contrast to Maruku, farmers chose a juice cultivar as one of the best cultivars.

The hybrids N9, N11, N27, and the local cultivar 'Mbwazirume' were the most preferred cultivars in Lyamungo (Table 4). Men preferred N27 first, N9 second, and N11 third. Women preferred 'Mbwazirume' first, N11 second, and N9 third. Across sites, N9 and N11 cultivars yielded an intermediate to high bunch weight (18 kg and 21 kg, respectively). N9 is a type of juice, whereas N11 is a type of food. Farmers preferred these cultivars because they have a large bunch, a large fruit cluster, a strong pseudostem, are apparent pathogen-resistant, and are commercially viable (Additional file 1: Table S6). While some farmers, mostly men, preferred compact fruit clusters because they are easier to transport in bulk and would therefore be able to sell more bunches to traders, others, like women, preferred more spaced fruit clusters because they are easier to chop banana fruit for cooking.

The results confirm that a farmer's perception of a cultivar or cultivar products can be impacted by its outward quality even before tasting it. According to Rocha et al. [52], cultivar and product appearance is one of the most important characteristics because it influences the market value of the product [53], and it is a critical component driving the initial purchase [2]. Farmers' preferences for large fruit were linked to women's dislike of small fruit due to difficulty in peeling and the need for more fruit clusters (notably 'hands') to feel the pot, which is not economically feasible for most rural households, which are typically overly extended.

The Mann–Whitney U test was used to confirm the difference in farmers' preference between local and hybrid cultivars at each site, based on the preference scores determined by each farmer's positive or negative votes assigned to each cultivar (Fig. 1). At the Maruku site in Tanzania and the Kawanda site in Uganda, the results revealed significant differences ($P < 0.05$) in cultivar preferences between local and hybrids (Table 5). At

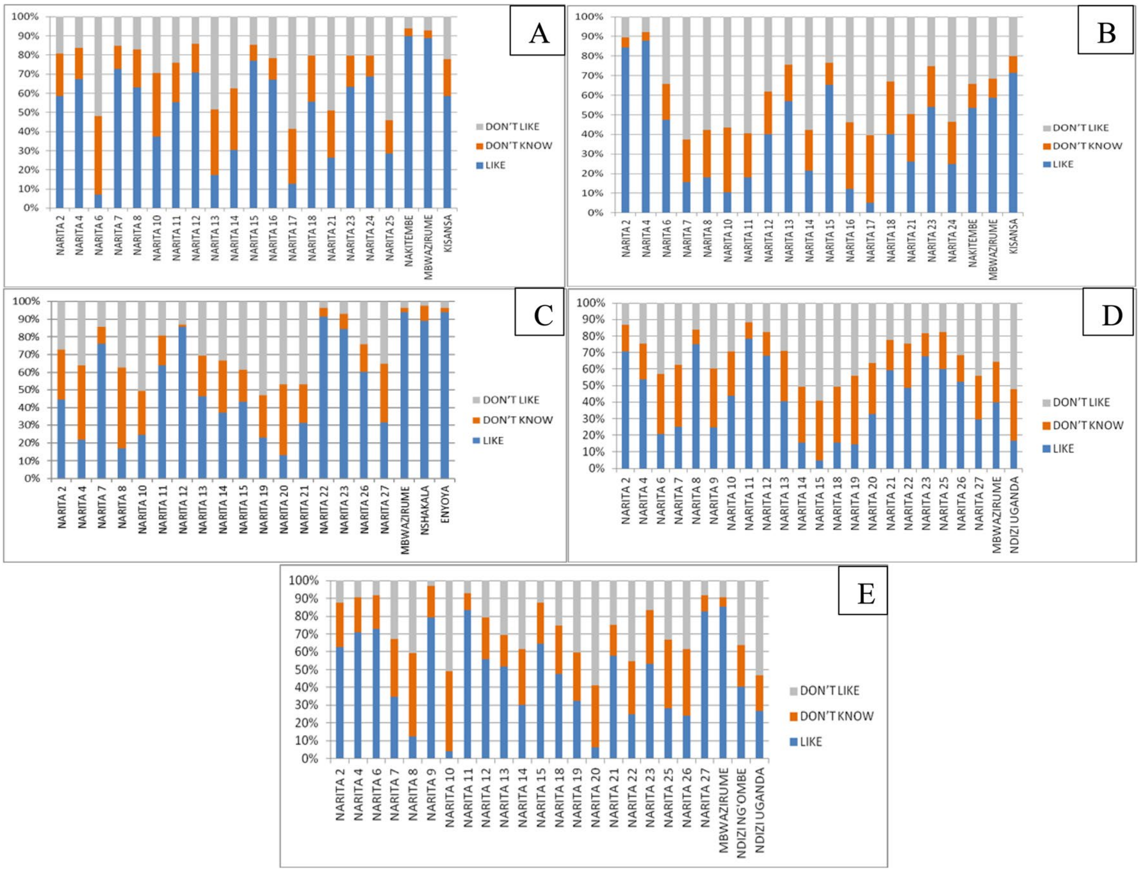

Fig. 1 Farmers' votes for preference ranking exercise in Uganda's Kawanda **A** and Mbarara **B**, as well as Tanzania's Maruku **C**, Mitalula **D**, and Lyamungo **E** sites. The figure depicts the actual votes casted by farmers in the five sites used to calculate preference scores

Table 5 Farmers' preferences difference for cultivars between local checks and hybrids

Site	Cultivar type	Lower preference score	Median preference score	Upper preference score	Mann–Whitney U	*P*-Value
Kawanda	Local	68.18	90.91		9.00	0.039**
	Hybrids	38.36	68.69	74.56		
Mbarara	Local	59.65	63.59		12.00	0.086 ns
	Hybrids	29.22	38.26	65.29		
Maruku	Local	93.37	95.12		1.00	0.003***
	Hybrids	40.96	52.41	76.62		
Mitalula	Local	32.25	42.11		10.00	0.134 ns
	Hybrids	40.74	57.31	72.91		
Lyamungo	Local	36.70	52.06		31.50	0.506 ns
	Hybrids	44.35	61.05	78.39		

** and *** indicate significant at $P<0.01$, and $P<0.001$, respectively, while ns indicates non-significant at $P>0.05$

Mitalula and Lyamungo in Tanzania, as well as at Mbarara in Uganda, the differences were non-significant ($P>0.05$). Three out of five sites revealed a non-significant difference in preferences between local and hybrid cultivars, thereby demonstrating how farmers value both local and hybrid cultivars due to the gains from their distinct characteristics. The findings also imply that people in Kawanda, Mbarara, and Maruku areas, where the

'Matooke' banana is a staple food and cash crop, may be more selective in accepting improved 'Matooke' banana cultivars than people in Mitalula and Lyamungo, where people are accustomed to other banana cultivars such as 'Mchare' and 'Itoki' (plantain) and thus more flexible to try new improved cultivars.

Farmers' decisions to accept new cultivars typically entail a series of sub-decisions on whether to try out new cultivars and whether to completely replace existing cultivars [54–56]. Farmers typically adopt improved banana cultivars if they discover only desirable quality or combinations of quality characteristics that are superior to and not found in their local cultivars. This is because choosing between two options involves trade-offs. Although hybrid cultivars' tastes deviate from that of local cultivars, they produce well and are pest and pathogen-resistant, as well as drought tolerant. On the other hand, local cultivars are better suited to local farming systems and socioeconomic structures, which is reflected by specific characteristics like sustenance of small harvests even water or nutrients are lacking, poor soils, pests, and pathogens, as well as preferred good food taste, flavor, texture, and color of the food when cooked. While breeders want to disseminate superior banana cultivars to farmers, they also want to preserve local cultivars for use as parental materials in their crossing blocks. Overall, hybrids were preferred over local cultivars in Mitalula and Lyamungo, while local cultivars were preferred in Maruku. Local cultivars were preferred over hybrids in Kawanda, whereas hybrids outperformed local cultivars in Mbarara.

Farmers' preferred characteristics

Farmers' approaches in defining characteristics were multivariate, with preferences for phenotypic features varying by site and country. This was especially true for characteristics such as yield, marketability, cultural relevance, and resistance to abiotic stress, pests, and pathogens. It was fascinating to note that farmers chose multiple characteristics, which is consistent with previous research indicating that smallholder farmers consider a variety of attributes when selecting and adopting cultivars [14, 57, 58]. Large bunch was the most desired characteristic among Tanzanian farmers, followed by bunch marketability and robust stem. Ugandan farmers prioritized large fruit, drought tolerance, robust stem, and phenotypic resemblance to local cultivars over all other characteristics.

The most important characteristics for farmers in both Tanzania and Uganda were large fruit, a large bunch, market acceptability of the banana bunch, a sturdy stem, and an attractive appearance of the banana plant. Farmers' desire for large bunch size, which indicates a cultivar's marketability, was expected as bananas became more commercial, and most buyers frequently prefer large bunch size over other characteristics [59]. High-yielding cultivars are preferred by farmers because they allow them to produce a surplus that can be sold to augment household income.

The fact that the appearance of banana plants was identified as a desirable characteristic suggests that farmers place importance to characteristics that can predict growth performance under specific conditions. Appearance determines the initial purchase price, which influences the market value of cultivar products. Farmers also mentioned regulated suckering with only a few suckers escaping apical dominance and developing into the ratoon crop, disease resistance, early maturity, banana leaf suitability for animal feeds, medium plant stature, cultural relevance, and local use such as the ability of plant residuals to make rope, food cover, or items to carry water, as well as the plant's ability to sustain leaves, all of which differed greatly between sites and countries. This is due, in part, to the different cropping systems of these locations' different agro-ecozones.

Despite the fact that banana pests and pathogens are significant issues in the region, farmers did not identify them as critical. This could be due to a lack of diseases in banana hybrids, implying that new banana cultivars are pest and pathogen-resistant, or to farmers' limited ability to identify pathogens, which could be related to farmers incorrectly identifying the cause and effect of the pest or pathogen. As a result, it has been proposed that science-based knowledge (breeders' knowledge) and local knowledge systems (farmers' knowledge) be integrated in agricultural research and development [60]. Adoption of participatory approaches is a practical example of this approach.

The banana leaf canopy shields other crops like beans (*Phaseolus vulgaris*) [61] and coffee (*Coffea spp.*) [62], which are frequently intercropped with bananas and thus highly valued by farmers. Banana plants with medium or low stature are preferred because they are less susceptible to hailstorms; however, a plant with more leaves works as a damage reducer during high winds, has a higher yield potential, and is less prone to pathogens.

Banana plants with more functional leaves produce a large bunch that seems to be more appealing to customers, whereas those with a wide girth are more resistant to storms and produce a bunch with more clusters, resulting in more revenue. The diversity of farmers' preferences is further confirmed by the fact that, while some farmers prefer a plant with many suckers for selling purposes of planting material, others prefer a plant with few suckers, arguing that a plant with many suckers needs more work in pruning and more manure. Farmers in Kawanda prefer short banana plants that can endure wind damage, but farmers in Mbarara want a tall plant stature, stating that a thief may simply grab the bunch from a short banana pseudostem. Farmers in Mitalula, like tall plant stature because it allows for intercropping with other crops and may improve the overall appearance of the field.

Ssali et al. [63] confirmed the complexity of farmer preferences in central Uganda's Nakaseke District. Farmers in this region preferred short banana plants that could withstand wind damage and were willing to "swap" with yield. Gold et al. [64] reported similar results. Farmers in southwest Uganda preferred cooking types, which they sold to traders who delivered to urban markets in Kampala, Mbarara, and Jinja [64, 65]. Farmers and traders in this region preferred cultivars that produced large, compact bunches that could be transported more easily. Farmers in Tanzania's Kagera region preferred cultivars with distinctive culinary characteristics as well as cultural significance or value [66].

Gender preferred characteristics

Farmers' preferences for varietal characteristics vary depending on the agro-ecological and socioeconomic settings in which they work, as well as their production objectives [24]. Knowing which characteristics are preferred by men and women farmers, as well as other value chain players, enables the development of novel cultivar product profiles with a higher chance of acceptance. PA was used to identify the preferred characteristics of women and men farmers, which breeders can use to develop banana cultivars that appeal to both groups. Gender preferences for characteristics differ according to several factors, including production systems, and the farmers' production goals. Men's most desired characteristics across sites were large bunch and marketability, followed by the provision of numerous suckers, large fruit, and vigor stem (Table 6). Women, on the other hand, preferred large bunch, which was followed by plant, bunch, and fruit appearance, vigorous stem, early maturity, and pest and pathogen resistance.

An investigation of gender preferences at the site revealed that women in Kawanda were most interested in the leaf suitability of the local cultivar 'Nakitembe' for steaming food, provision of healthy suckers, high yield, and associated characteristics such as resistance to *P. fijiensis* causing black leaf streak and its ability to survive the dry season. Men admired it for its large bunch, which increased market value, as well as its early maturity and bacterial wilt resistance caused by *Xanthomonas campestris* pv. *musacearum* (Additional file 1: Table S2).

The hybrid N4 was the most preferred cultivar in Mbarara among men farmers for its small stature, large bunches, and large fruit, as well as the fact that it produced healthy suckers with numerous leaves and phenotypically resembled the local cultivar 'Enjagata', while women farmers liked N4 for its drought tolerance, suckering ability, and attractive appearance (Additional file 1: Table S3). It is clear that the preferred characteristics fall into two categories: production and consumption use preferences. Men, for example, were more concerned with bunch yield and marketability, whereas women had broader preferences that included plant, bunch, and fruit appearance, plant stature, cooking qualities such as suitability of leaves for food steaming, and the plant's ability to generate by-products in addition to yield and marketability (Additional file 1: Table S3 and S3).

Farmers in Maruku, both men and women, preferred the local cultivar 'Mbwazirume' to hybrids. Men liked it because of its large fruit and ability to produce by-products like rope for tying grasses, thatching, and making poaches and hut caps, while women liked it because of its high yield and cultural relevance, especially at weddings (Additional file 1: Table S4). Bunch acceptance by market consumers was mentioned as a common characteristic for both genders' preferences. Among the top three cultivars selected in Maruku, N22 was the only hybrid preferred by farmers. Men praised its strong stem and ability to retain a large number of leaves for feeding animals, while women praised its appealing appearance and drought tolerance. These findings support the assertion by Christinck et al. [24], who indicated that sometimes women and men do not require separate cultivars, but rather cultivars with characteristics that are preferred by both. Breeding will contribute more effectively to addressing gender-differentiated preferences if integrated and is based on a thorough diagnosis of the diverse strategies, desires, and priorities of men and women growing bananas.

N11 was the most preferred hybrid in Mitalula. Men were more interested in the bunch's marketability and phenotypic similarity to local cultivars, whereas women were more concerned about the bunch's ability to withstand harsh environments, produce large fruit, and be pathogen and pestresistant (Additional file 1: Table S5). There was no local check among the top three most preferred cultivars in Mitalula. In Lyamungo, farmers' preference for the hybrid N9 was intriguing. Despite the fact that it is a juice cultivar, men preferred it due to its high yield and resistance to drought and pathogens. Women, on the other hand, were more concerned with the plant's stature, which allows for intercropping, ability to produce a large number of fruit in a cluster, and marketability (Additional file 1: Table S6). Men and women listed similar characteristics in different ways on occasion, but the ways in which these characteristics were expressed varied as well. Men, for example, stated unequivocally that they

Table 6 Sex-disaggregated rationale for banana cultivars' preferences. The reasons listed have been summarized from FGDs in all study sites for farmers' preferred cultivars

Cultivar	Reasons for preference Men	Reason for preference Women
**Mbwazirume	• Large bunch • Large fruit • Vigorous stem • Bunch marketability • Can survive in dry conditions • It contains fibers that can be utilized to make various by-products	• Large bunch • Large fruit • Vigorous stem • Appealing plant appearance • Tolerance to drought • High cultural importance
*NARITA 4	• Long bunch • Bunch marketability • Large fruit • Short plant stature not easily damaged by wind • Suckers grow close to mother plants • Retain many leaves	• Large fruit • Appealing fruit appearance • Appealing plant appearance • Vigorous pseudostem • Medium plant stature • Resembles local cultivars • The leaves can be used to prepare and steam food
*NARITA 22	• Large bunch • Appealing fruits appearance • Bunch marketability • Vigorous stem • Resistance to drought • Produce healthy suckers • Retains many leaves	• Large bunches • Large fruit • Bunch marketability • Appealing plant appearance • Tolerant to drought
*NARITA 11	• Large fruit • Bunch marketability • Appealing fruit cluster appearance • Resembles local cultivars	• Large fruit • Large bunch • Vigorous stem • Not affected by diseases
*NARITA 2	• Well-defined large fruit cluster • Bunch marketability • Appealing plant appearance • Tall plants making the field look attractive	• Long bunch • Attractive bunch appearance and compact • Vigorous stem • Many leaves that can be used for animal feed
*NARITA 9	• Large bunch • Bunch marketability • Vigorous stem • Host plant resistance • Tolerant to drought	• Large fruit • Many fruit clusters • Bunch marketability • Host plant resistance • The plant has a good stature that allows for intercropping
**Nakitembe	• Large bunch • Vigorous stem • Not affected by diseases (no symptoms of *Xanthomonas* bacterial wilt) • Many suckers	• Compact fruit • Appealing fruit appearance • Appealing plant appearance • Provides many and healthy suckers • Appeared to be able to withstand harsh climatic condition and hailstorms Has nice leaves for steaming 'Matooke' food

* NARITA hybrids

** Local cultivars grown by farmers used as checks

preferred the marketable banana bunch; women, on the other hand, demonstrated how it shortened market selling time and commanded a premium price.

Weltzien et al. [26] found that women's varietal characteristic preferences are more frequently associated with food security characteristics such as early maturation, post-harvest processing, and food preparation. Farmers are aware of their local environment and the essential characteristics that new cultivars must possess, especially as they work to adapt to their stressful production systems and environments. Farmers' preferences for cultivars characteristics are thus complex, taking into account factors other than pathogen resistance and yield-related characteristics. When planning varietal improvement programs at various levels—specifically, internationally, regionally, nationally, and locally—both a sound methodology and gender-inclusive participation structure are required.

The paired Wilcoxon signed-rank test was used to confirm the differences in cultivar preferences between men and women farmers. At Maruku and Mbarara, men and women's preferences differed significantly ($P < 0.05$), but not at Mitalula and Lyamungo sites in Tanzania or the Kawanda site in Uganda (Table 7). Women and men can choose and grow the same or different banana cultivars under similar or dissimilar conditions for a variety of reasons. They have distinct characteristic preferences, particularly when confronted with distinct production constraints, distinct roles and responsibilities in production and consumption systems, and distinct crop production objectives [24, 45]. All sets of factors are variable and fluctuate over time, whereas coping strategies for adjusting to these changes and achieving relevant production goals may differ between farmer groups, for example, based on resource and capital endowments or available infrastructure.

Plant breeders can best contribute to these transformations by improving their understanding of these shifts and related strategies, allowing them to predict interesting characteristics and characteristic combinations for the crops, cropping systems, and farmer groups they are targeting. In other words, they must establish a system understanding and define their breeding activity based on the identification of relevant characteristics that suits both genders [67]. On the other hand, an important implication of the wide range of farmers' preferred characteristic combinations is the need to involve farmers in crop cultivar evaluation in order to define minimum sets of basic characteristics and understand farmers' adoption and rejection criteria. This strategy will reduce the development of cultivars with characteristics that farmers will eventually reject during on-farm trials because farmers would have an early opportunity to exchange views about the cultivars with agronomists, social scientists, and breeders.

Farmer's selection criteria

Farmers were asked to list the key selection criteria they use when choosing a banana cultivar; i.e., the characteristics that influence their liking and dislike of the cultivars. Farmers in Uganda and Tanzania assigned different weights to the selection criterion (Table 8). Farmers mentioned bunch size (large, long, compact, and pleasing appearance) as the most important selection criterion across all the sites, followed by large fruit and fruit clusters, pathogen and pest resistance, and vigor of the pseudostem. Marketability, drought tolerance, moderate plant stature, and culinary qualities (easy peeling, good taste, deep yellow color after cooking, and short cooking time) were all equally important additional criteria in farmers' cultivar selection (Table 8). Despite the fact that preference ranking is a visual evaluation exercise, these findings revealed the breadth of farmers' selection criteria, which include intrinsic and extrinsic attributes, as evidenced by the sensory characteristics mentioned by farmers. Farmers desired, but did not prioritize, the availability of a large number of suckers, the attractiveness of the plant's appearance, and cultural importance as criteria.

Individual site analysis revealed that the majority of Tanzanian farmers in Maruku, Lyamungo, and Mitalula sites made their visual selection based on criteria for bunch yield and culinary attributes (Table 8). Only a few cultivars were chosen based on criteria such as early maturity, marketability, and resistance to pathogens and pests. Farmers in Uganda's Kawanda and Mbarara sites selected cultivars based on pest and pathogen resistance, vigor of the pseudostem, plant stature, and bunch size. Fruit size, suckering ability, phenotypic similarity with local cultivars, provision of many leaves, drought tolerance, and early maturity were all mentioned by farmers.

Table 7 Men and women farmers' preferences differences for tested cultivars

Sites	Men and women preference scores	Quartiles			Mean rank		*P*-Value
		Lower preference scores	Median preference scores	Upper preference scores	Negative R	Positive R	
Kawanda	Men	47.50	60.00	79.47	9.44	11.36	0.239 ^{ns}
	Women	42.09	69.23	78.98			
Mbarara	Men	27.89	48.76	65.31	9.17	11.07	0.031 **
	Women	32.94	55.18	66.27			
Maruku	Men	44.55	57.64	88.89	13.60	7.40	0.261 ^{ns}
	Women	40.96	57.54	86.44			
Mitalula	Men	35.80	56.82	74.44	13.79	9.22	0.049 **
	Women	36.90	53.57	66.67			
Lyamungo	Men	40.10	60.11	82.40	10.36	14.31	0.316 ^{ns}
	Women	50.26	60.62	78.19			

** indicate significant at $P < 0.01$, while ns indicates non-significant at $P > 0.05$

Table 8 Ranking of farmers' selection criteria in five Tanzanian and Ugandan testing sites, disaggregated by gender

Criteria	Men							Women							Men and women mean ranks	Overall rank
	Kawanda	Mbarara	Maruku	Mitalula	Lyamungo	Mean rank	Men rank	Kawanda	Mbarara	Maruku	Mitalula	Lyamungo	Mean rank	Women rank		
Large bunch	1	1	1	2	1	1.20	1	2	3	1	1	1	1.60	2	1.40	1
Large fruit and fruit clusters	2	2	2			2.00	2	1		2			1.50	1	1.75	2
Market-ability	5		3			4.00	6							12	4.00	6
Attractive appear-ance of plants	3	7				5.00	8		7	3		4	4.67	9	4.83	10
Vigor stem	4	3		1		2.67	4	5	1		2		2.67	4	2.67	4
Provision of suckers		5	7			6.00	12	3	2			5	3.33	5	4.67	9
Drought resistant	7				3	5.00	9		5			3	4.00	7	4.50	8
Pathogen and pests resistant					2	2.00	3				3	2	2.50	3	2.25	3
Early maturity (3 to 4 month)	8					8.00	14		4	5			4.50	8	6.25	14
Good taste, easy to peel, soft, yellow when cooked and short cooking time	6		4		4	4.67	7			4			4.00	6	4.33	7
Many leaves		6				6.00	13	4	6				5.00	10	5.50	13

Table 8 (continued)

Criteria	Men							Women							Men and women mean ranks	Overall rank
	Kawanda	Mbarara	Maruku	Mitalula	Lyamungo	Mean rank	Men rank	Kawanda	Mbarara	Maruku	Mitalula	Lyamungo	Mean rank	Women rank		
Tall or moderate stature		4		3		3.50	5							11	3.50	5
Produce by-products			6		5	5.50	11							14	5.50	12
Cultural importance			5			5.00	10							13	5.00	11

Farmers in both countries emphasized plant and bunch attractiveness or appearance as a critical criterion, particularly for marketing purposes.

Men's criteria were more concerned with production characteristics such as bunch yield and vigor of the pseudostem, whereas women's criteria were more concerned with consumption characteristics such as overall plant appearance, marketability, and culinary qualities, in addition to production-related characteristics (Table 8). The Spearman's rank correlation was significant ($r=0.6$, $P=0.03$), thus demonstrating a strong positive relationship between the ranks based on men and women selection criteria. Before making a final decision to adopt a cultivar, farmers evaluate the attributes of all competing cultivars, particularly landraces. This procedure is not explicitly stated, and the primary goal is to maximize perceived value.

Conclusion

Farmers in Uganda and Tanzania prefer many characteristics together for adopting improved 'Matooke' cultivars that include factors other than yield-related characteristics. The primary drivers of farmer preference selections in this study were yield, plant growth, bunch marketability, culinary characteristics, and stem vigorousness. Farmers in Uganda and Tanzania assess the cultivar's overall value as they see it, allowing them to forecast how it will perform under specific conditions. These findings imply that breeding for productivity and consumption characteristics should remain a top priority for banana improvement. Women and men do not require different cultivars, according to gender preferences analysis, but rather cultivars with characteristics that both genders prefer. If breeding is based on a comprehensive analysis of the different strategies, goals, and priorities of men and women cultivating bananas in their plots, it will contribute more effectively to resolving gender-differentiated characteristic preferences. Given the diversity of consumer preferences, genetic structure, and the relationship between genetic make-up and environment, no single cultivar can provide all of the attributes desired by farmers. In Tanzania and Uganda, for example, most farmers plant a diverse range of cultivars in order to capitalize on their distinct advantages in terms of consumption and production requirements, resulting in a high degree of diversity of banana cultivars on a single farm. Furthermore, farmers who adopt improved cultivars are more likely to continue planting local cultivars in order to capture desirable production and consumption characteristics, as well as to ensure better compatibility with local farming systems, varying ecological conditions, and socioeconomic structures. Therefore, knowing farmers' general production goals will be a general criterion for successfully developing banana cultivars that meet their requirements, as they employ numerous cultivars in different cropping systems under varying ecological conditions and at different levels of management. This is critical in terms of their livelihood and survival strategy, as well as the value of farming, cultivation methods, uses, and key constraints to increasing yields or generating income. The use of participatory approaches must be prioritized in order to better understand these variations and increase the likelihood of widespread adoption. Furthermore, the study's findings suggested that breeding strategies should target region or country-specific preferences in order to increase farmer acceptance of improved 'Matooke' banana cultivars.

Abbreviations

EA	East Africa
ECA	East and Central Africa
PVS	Participatory varietal selection
EAHB	East African highland banana
NARO	National Agriculture Research Organization
IITA	International Institute of Tropical Agriculture
TARI	Tanzania Agriculture Research Institute
TaCRI	Tanzania Coffee Research Institute
RCBD	Randomized complete block design
PA	Preference analysis
PS	Preference score
SPSS	Statistical Package for Social Science
FGDs	Focus group discussions

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40066-023-00407-7.

Additional file 1: Table S1. Dates of farmers visits to the five sites in Tanzania and Uganda for preference ranking. **Figure S1.** The number of farmers who took part in the preference ranking exercise at each of the five Tanzanian and Ugandan sites. **Table S2.** Reasons given by participants for (not) selecting banana cultivars in Kawanda, disaggregated by gender. **Table S3.** Reasons given by farmers for (not) selecting banana cultivars in Mbarara, disaggregated by gender. **Table S4.** Reasons given by farmers for (not) selecting banana cultivars in Maruku, disaggregated by gender. **Table S5.** Reasons given by farmers for (not) selecting banana cultivars in Mitalula, disaggregated by gender. Table S6. Reasons given by farmers for (not) selecting banana cultivars in Lyamungo, disaggregated by gender.

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Author contributions

The manuscript was conceptualized, developed, and written by NM. The entire research was supervised, guided, and corrected by RO, RS, EW, SC, and AB. The development of protocols and improvement of data collection tools was aided by IV, RC, and PM. The exercise was planned and executed with help from CM, MS, DM, GK, JK, AO, and RT, who also revised the manuscript. MC made edits to the paper. All authors agree and consent for the article to be published. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets that support findings of this study are available from the corresponding author.

Declarations

Ethics approval and consent to participate

The National Agriculture Research Organization of Uganda and the Tanzania Agriculture Research Institute, both of which have the legal authority to conduct research in their local communities and engage with farmers, were contacted to request permission to carry out the preference ranking exercise in the areas under their respective research jurisdiction. On the day of the exercise, every participant's respondent gave their consent to take part in the preference ranking.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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