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The role of variety attributes in the uptake of new hybrid bananas among smallholder rural farmers in central Uganda

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Abstract

Background: While advances in agricultural research and development have led to generation of improved new cooking hybrid banana varieties (HBVs) with enhanced yield potential to restore production levels, these have been received with mixed feelings on production and consumption attributes among the farming communities in Uganda. Some farmers prefer HBVs that are comparable to their local varieties in terms of consumption attributes such as soft food, color when cooked, flavor and taste while others prefer high-yielding HBVs to produce surplus output for sale.

Methods: Using cross-sectional survey data from 242 randomly selected smallholder banana farmers in Nakaseke and Luwero districts in Central Uganda, the study applied a Tobit regression model to analyze the influence of socio-economic factors and variety attributes on the adoption of new hybrid bananas.

Results: The results on the perception of farmers on banana variety attributes showed that the new HBVs had desirable production-related attributes, while local cultivars were rated superior to hybrids on consumption-related attributes. Evidence further showed that production-related and consumption-related attributes influenced farmers' decisions in the adoption of HBVs. Further, an assessment of the socio-economic factors that influence the adoption of HBVs showed that education of the farmer, household size, interaction with different banana actors, experience (number of years growing HBVs), and source of planting materials had a significant influence on farmers' adoption of the new HBVs.

Conclusion: The study findings provide insights into the need for agricultural research and development initiatives to target the development of banana varieties with multi-traits that meet end-users' preferences and needs. Facilitating the establishment of multi-actor platforms that bring together the different actors to share information and learn might be useful in increasing the intensity of HBVs adoption.

Keywords: Adoption, Hybrid banana varieties, Intensity of adoption

Background

Progress towards attainment of food security remains a challenge in sub-Saharan Africa (SSA) partly due to low agricultural productivity [1]. Technological improvements, particularly yield-enhancing technologies offer opportunities for improving agricultural productivity and ensuring global food security [2]. Therefore, efforts geared at research and development continue to receive considerable attention with investments directed towards

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the development of new varieties and breeds for priority enterprises.

Banana is one of the crops critical to global food security in SSA, and in Uganda, it is a priority crop since it is a source of food and income for many households [3]. The East African highland cooking banana type, locally known as '*Matooke*', is the most important group of cultivars grown in the country [4]. In recent years, production levels have reduced due to pests (banana weevils and nematodes), diseases (*Fusarium* wilt, bacterial wilt and black Sigatoka) and drought stress [5]. The crop has received varying research and development efforts in a bid to avert the declining production levels. In Uganda, the National Agricultural Research Organisation (NARO) has since 1994 conducted research using different approaches including introduction and evaluation of accessions, conventional breeding, transgenic breeding and biotechnology to produce banana varieties that are resistant or tolerant to pests and diseases, and meet the end-user needs. Previous research shows that the hybrids initially introduced (called FHIA) did not meet the needs of end-users especially banana farmers in the lowland areas around the Lake Victoria crescent zone [6]. It was estimated that less than 50% of the introduced hybrids met the needs and preferences of end-users [7], which prompted the researchers to intensify breeding efforts towards development of other cooking banana (*matooke*) varieties with desirable attributes.

In collaboration with the International Institute of Tropical Agriculture (IITA), NARO embarked on a banana breeding program that has led to new cooking banana type hybrids herein referred to as the new hybrid banana varieties (HBVs). To date, two HBVs (KABANA 6H and KABANA 7H) have been released and these have been further promoted through uptake pathways as a means to restore production levels in central Uganda [8]. Opportunities for processing bananas into various products exist given its high demand and calls for more efforts to ensure increased improved banana output. However, recent reports indicate that the new HBVs have been received with mixed feelings and perceptions among the farming communities [9], especially in central Uganda which was the main targeted region for the varieties. While some farmers considered the new varieties as an avenue to overcome low productivity due to associated higher productivity and resistance to pests and diseases and therefore improve the food security situation, others farmers rejected the hybrids on perceived consumption attributes of poor taste and flavor [8]. To understand why banana farmers have mixed feelings and perceptions on HBVs, it is imperative to investigate the influence of variety attributes on farmers' decision to adopt HBVs. Over the years, new trends in processing, value addition, marketing and consumption have emerged which calls for further investigation into the factors that influence the rate of HBVs adoption.

From innovation adoption literature, several studies have assessed the factors influencing agricultural technology adoption in sub-Saharan Africa. These factors range from technology-specific attributes; farmer, household and farm characteristics; and institutional factors. Technology-specific attributes such as those related to production (pest/disease resistance, tolerance to drought, tolerance to poor soils) and consumption (food taste, color and texture) have been found to be important determinants of adoption [10–12]. Among the farmer, household and farm characteristics that influence technology adoption are farmer's age, sex, education level, household size, income level and farm size while the institutional factors include membership to farmers' groups, access to credit, markets, agricultural information and extension services [13, 14]. Past studies have reported mixed results on the influence of these factors on agricultural technology adoption. For instance, farmers' education level has been reported to have a positive and negative influence on adoption under different circumstances. Although studies such as Kiyingi et al. [15] and Katungi et al. [11] report a positively significant relationship between education level and adoption of agricultural technologies, others such as Kikulwe et al. [16] and Akankwasa et al. [17] found a negatively significant relationship. Further, Katungi et al. [11] reported that while education had a positive effect on area allocated to common bean varieties with relatively preferred attributes, it reduced land allocation to the risk increasing variety when other factors including farm size are controlled. Similarly, while some studies [12, 18] established that adoption of agricultural technologies was positively influenced by farm size, other studies [19] found a negatively significant relationship between two variables. The negative influence of farm size on technology adoption is mainly explained in terms of farmers' risk aversion since a new technology may entail unknown risks.

Although several empirical studies exist on adoption, few studies have specifically analyzed the adoption decision for cooking banana hybrid varieties in Uganda. Limited empirical evidence exists on the relative importance of variety attributes along with the farmer, household and farm characteristics and institutional factors in the adoption of new hybrid banana varieties. Existing studies have mainly focused on early-stage (ex ante) adoption of these varieties to explain the likelihood of farmers' adoption and consumers' willingness to purchase the matooke hybrids using experimental data [20]. This study goes a step further to explore the empirical determinants of adoption and intensity of adoption of new HBVs among smallholder farmers in central Uganda. Therefore, the study's contribution to literature is twofold. First, it explores the role of variety attributes in HBVSs adoption decisions. Second, our data allow us to capture both adoption and intensity decisions among banana farming households. The rest of the paper is structured as follows: section two presents the methodology, followed by results and discussion in section three, and key policy recommendations in the last section.

Methodology

Study area

The study was conducted in the Central region of Uganda, in Nakaseke and Luwero districts (Fig. 1).

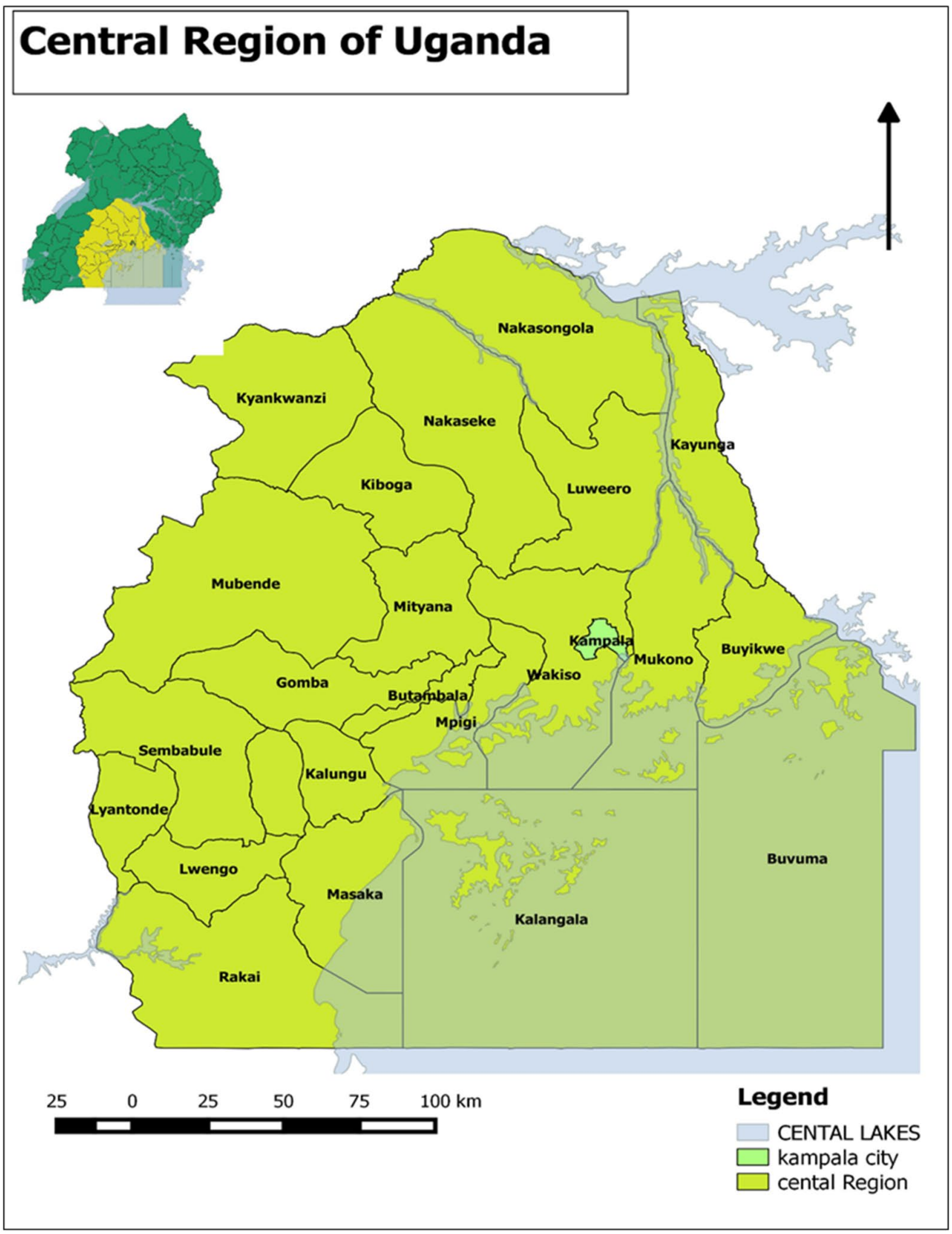

Fig. 1 Map showing the study area

Nakaseke District is bordered by Nakasongola District to the north and northeast, Luweero District to the southeast, Wakiso District to the south, Mityana District to the southwest. Kiboga District and Kyankwanzi District lie to the west and Masindi District lies to the northwest. While Luweero District is bordered by Nakasongola District to the north, Kayunga District to the east, Mukono District to the southeast, Wakiso District to the south, and Nakaseke District to the west. The central region was purposively selected because it is one of the major banana producing areas yet experienced a drastic decline in productivity due to the aforementioned constraints [21]. It is estimated that about 58% of agricultural households in this region grow bananas. The crop is grown on an estimated mean plot size of 0.30 ha which is the highest compared to all regions and the national-level mean of 0.28 ha [21]. Most of the banana plantations (64%) in the region are grown in mixed stands with coffee, a practice that farmers consider to be resilient to agro-ecological and economic shocks and stresses [22].

Study design and sample selection

The study employed a quantitative research design and data were obtained through a cross-sectional survey conducted in February 2016. The study aimed at identifying factors that influence the uptake of new HBVs and hence this design was most suitable since it collects data that can be used to compare different groups of farmers, i.e., users and non-users of new HBVs at a single point in time. Questionnaires were administered to selected respondents to generate data on different variables of interest.

A multi-stage sampling procedure employing both non-probability and probability sampling techniques was used. Non-probability sampling was employed to select study sites and generate the sampling frame. For study sites, two districts (Nakaseke and Luwero) were purposively selected due to their prior participation in banana research and development activities and efforts by NARO to sustain banana production. The districts hosted the first on-farm experimental trials for the hybrid lines initiated in 2000 to engage farmers in selection of the best lines (based on a set of criteria) that could be released to end-users [23]. In each district, one major banana-growing sub-county participating in NARO's banana interventions—(Kasangombe and Makulubita in Nakaseke and Luwero, respectively) was selected. This was then followed by the selection of all the participating parishes in each sub-county, and these included Bukuuku, Bulyaake, Nakaseeta and Sakabusolo from Nakaseke district and Mawale parish in Luwero district.

The non-probability sampling further involved purposive selection of all banana farmers in each of the selected parishes to generate the sampling frame. The sampling frame was generated with the help of community-based facilitators (CBF); a total of 1689 farmers were selected. The proportionate-to-size method was used to compute the number of farmers to be *randomly* selected from each of the parishes and 53 (Bukuuku), 54 (Bulyaake), 67 (Nakaseeta), 25 (Sekabusolo), and 58 (Mawale) farmers were randomly selected. In total, 257 farmers were selected, but only 242 banana farmers were successfully interviewed representing a response rate of 94.2%.

Data collection

Data were collected from the 242 randomly selected farmers using a questionnaire. To test for suitability and reliability, the survey tool was pre-tested in a different but neighboring sub-county and then modified for clarity and sequencing of questions based on the pre-test experiences and results. Actual data collection was through face-to-face interviews with the respondents focusing on individual and household characteristics, farm characteristics, institutional and access-related factors, and banana varieties grown and their preferred attributes. The farmer preferences for the varietal attributes (production and consumption) were measured using a five-point ranking scale where 1 = least important and 5 = most important.

Theoretical framework

For smallholder farmers in Uganda (comprising over 65% of the total population), production and consumption decisions are non-separable, i.e., production decisions are affected by consumption decisions. Therefore, we analyze the adoption of HBVs within the theory of agricultural household models [24, 25]. According to this framework, households combine farm resources and family labor to maximize utility over leisure and consumption goods produced on the farm. Farm decisions are constrained by a production technology, conditioned on the farm's physical environment; family labor time allocated to labor and leisure; and a full income constraint. The theory of the agricultural household is suitable for analyzing the decisions of farmers who operate with missing or imperfect markets. Smallholders produce goods including HBVs for consumption and sale (at local markets). Due to limited access to credit, farmers overcome cash constraints for (food) consumption through farm sales, sell livestock or farm equipment, and family members taking on off-farm jobs. In addition, financial markets are weak with limited access to various input and output markets. In this environment characterized by market failures, market prices do not reflect the full opportunity cost of various goods, particularly inputs and services such as agricultural knowledge and fertilizer. Consequently, we model farmers' HBVs adoption decisions as the result of a constrained utility maximization problem for a farming household [24].

Following the agricultural household theory and constrained utility maximization model of Singh [24] and later by Sadoulet and De Janvry [25], the household chooses a vector of consumption levels (*X*, *Z*) such that the general solution to the maximization of household utility under the binding constraints is a set of constrained optimal production and consumption levels (*X*, *Z*):

$$X = f(P, Y_c, \emptyset_{hh}, \emptyset_{farm}, \emptyset_{market}), \quad (1)$$

and

$$Z = f(P, Y_c, \emptyset_{hh}, \emptyset_{farm}, \emptyset_{market}), \quad (2)$$

where P represents prices; Y represents the full income constraint (which stipulates that a season's expenditure of time and cash cannot exceed the sum of the net farm earnings and income that is exogenous to farm choices); X represents consumption of goods produced on the farm; Z represents all other purchased goods, given a vector of exogenous socioeconomic and household characteristics, $\emptyset_{hh}$, a vector of exogenous farm physical characteristics, $\emptyset_{farm}$, and a vector of market characteristics, $\emptyset_{market}$. The household's adoption decision can be expressed in reduced form as an indirect function of price, income, household, farm, and market parameters:

$$\text{Adoption} = f(\text{P}, \text{Y}_c, \emptyset_{hh}, \emptyset_{farm}, \emptyset_{market}). \quad (3)$$

Embedded in the production technology, $\emptyset_{farm}$ are the variables. Following Eq. (3), the regression model is a reduced-form equation that relates to adoption and explanatory variables is given by

$$\text{Adoption}_i = \alpha + \beta_1 X_i + +\varepsilon_i, \quad (4)$$

where X_i represents exogenous factors ($\emptyset_{hh}, \emptyset_{farm}, \emptyset_{market}$). The choice of explanatory variables was guided by existing literature on agricultural adoption [10, 12–18].

Adoption and intensity of adoption of new HBVs—a Tobit analysis

When introduced to new technologies such as HBVs, farmers either decide to adopt or decline, given differing resources, education, aims and utility preferences hence positive decisions take a unit value while negatives a zero value. Qualitative response models such as Probit, Logit and linear probability models are the most feasible when analyzing such a dichotomous dependent variable [26]. However, the biggest shortcoming of these models is that they do not measure the intensity of technology adoption, which makes the Tobit model the most appropriate model to analyze both adoption and intensity of adoption. In addition, the model helps to avoid lumping of all banana farmers who did not grow HBVs as zero or and those who planted HBVs as one, thereby masking variation in the dependent variable (number of HBVs plant mats).

We consider the different HBVs available to banana farmers. The farmers have to decide which HBVs to grow (adoption decision), and if they adopt any HBV, how many mats (a plant mat is the whole set of banana plants emerging from the initial plant) to plant given the competing needs on available land (the intensity of adoption). We employ a Tobit model to analyze the determinants of both adoption and intensity of adoption of HBVs. The dependent variable is the number of banana plant mats and this is censored with a lower limit as zero and upper limit as continuous depending to the number of HBV mats planted on the farmers' farm. According to Greene [27, 28], a generalized two-tailed Tobit model is specified as:

$$y_i^* = \alpha X_i + \varepsilon_i, \quad (5)$$

where y_i^* is a latent variable (unobserved for values smaller than zero), α is a vector of coefficients to be estimated, X_i is the vector of explanatory variables, ε_i is a vector of independently normally distributed error terms with zero mean and constant variance σ^2, and $i = 1, 2, \ldots n$ (n is the number of explanatory variables). Denoting y_i (the number of banana mats planted) as the observed dependent (censored) variable, instead of observing y_i^*, we observe y_i :

$$y_i = \begin{cases} 0 \text{ if } y_i^* \leq 0 \\ y^* \text{ if } y^* > 0 \end{cases}. \quad (6)$$

Following McDonald and Moffitt [29], the effect of an independent variable on the expected value of the dependent variable for all observations can be decomposed into two parts: the change in the dependent variables of those observations above the limit, weighted by the probability of being above the limit; and the change in the probability of being above the limit, weighted by the expected value of the dependent variable above. To this effect, the expected value of y in the Tobit model is given by:

$$\text{Ey} = X\beta F(z) + \sigma f(z), \quad (7)$$

where $z = X\beta/\sigma, f(z)$ is the unit normal density and $F(z)$ is the cumulative normal distribution function, σ is the standard deviation of the error term that is reported in the Tobit results. The expected value of y for observations above the limit, here called y^* is given by:

$$Ey^* = X\beta + \sigma f(z)/F(z). \tag{8}$$

.

From Eqs. (7) and (8), the basic relationship between the expected value of all observations, Ey, the expected value conditional upon being above the limit, Ey*, and the probability of being above the limit, F(z) is given by:

$$Ey = F(z)Ey^*. \tag{9}$$

Thus, the effect of X on Y is given by:

$$\frac{\partial Ey}{\partial X_i} = F(z) * \frac{\partial Ey^*}{\partial X_i} + Ey^* \frac{\partial F(z)}{\partial X_i}. \tag{10}$$

From Eq. (10), it can be shown that the effect of an independent variable on the expected value of the dependent variable for all observations can be decomposed into two parts. The first part measures the probability of adoption and the second part measures the intensity of adoption; and both adoption and intensity decisions are conditioned on the farmer's socio-economic characteristics and technology-specific attributes among other factors.

Data processing and analysis

We processed the data with the Census and Survey Processing application (CSPro 6.2) and STATA, version 14 for entry and analysis, respectively. We did general exploratory analysis to determine the distribution of data for the continuous variables such as age, education, household size, income, farm size and proportion of land allocated to bananas and new HBVs. Diagnostic tests were further carried out to establish whether there was any significant correlation between any two independent variables to be included in the model estimation.

Correlations between the 14 variety attribute preferences indicated very high correlations and significant coefficients between them. We therefore subjected the attributes to data reduction procedures using principal components factor analysis method to extract a set of factors to be treated as uncorrelated variables to handle multicollinearity in the econometric analysis. Based on the criterion of an Eigen value greater than 1 [30], the 14 variety attributes were grouped into three independent attributes according to three unobserved factor loadings in absolute terms (Table 1). The three extracted factors explained 65.2% of total variance in the stated preferences for variety attributes subjected to factor analysis. Specifically, factors 1, 2 and 3 accounted for 43.7%, 11.7%, and 9.8% of the total variance, respectively. The first factor seems to indicate production-related attributes and loads most strongly on variables related to biotic and abiotic stress resistance. The second factor loading seems to indicate consumption-related attributes, whereas the third factor reflects agronomic related characteristics. Thus, the factors (1–3) are interpreted as: production traits, consumption attributes and agronomic traits related indices, respectively. These three underlying latent factors were then included in the econometric analysis as explanatory variables.

Table 1 Factor loadings for varietal attribute preferences (n = 87)

Variety attribute	Factor loadings[a]		
	Factor 1	Factor 2	Factor 3
Tolerance to drought	0.809		
Tolerance to poor soils	0.791		
Tolerance to pests and diseases	0.701		
Bunch size	0.685		
Early maturity period	0.614		
Sucker production	0.610		
Taste		0.830	
Texture when cooked		0.679	
Flavor		0.677	
Color of the food when cooked		0.652	
Plant height			0.892
Resistance to wind			0.788
Eigenvalues	5.241	1.401	1.177
% of variance explained	43.675	11.674	9.808

[a] Extraction method: principal component analysis and rotation method: Varimax with Kaiser normalization. Only attributes with absolute factor loadings > 0.5 are included

Farmer preferences scored on a scale of 1–5 and then recorded as a binary, where 1 = important attribute, 0 = not important

Results and discussion

Descriptive statistics

Different approaches were applied to describe the study sample. The banana-growing households were categorized into two groups of new HBV adopters and non-adopters. Table 2 presents a summary of key descriptive statistics that characterize the two groups. The average age of banana farmers was 48 years, although heads of adopter households were relatively older (51 years on average) than non-adopters (49 years). The average number of years of formal education for all farmers was about seven (7) years. On average, the household size was 7 persons, but HBVs adopter households had a slightly bigger household size (7 members) compared to non-adopters (6 members). The average land size for all households was 1.8 ha, with an average of about 1.5 ha (approximately 83%) allocated to crops and about 0.4 ha (approximately 29% of the crop area) to banana production. HBVs adopters reported significantly more total land owned (about 2.2 ha) and allocated to banana production (0.5 ha) as

Table 2 Summary of the descriptive statistics for the sampled banana farmers

Explanatory variables	Overall (n = 242)	HBVs adopters (n = 87)	HBVs non-adopters (*n* = 155)	Difference
Age of farmer (years)	47.9	47.9	47.9	0.006
Formal education of farmer (years)	7.3	7.3	7.2	0.040
Age of household head (years)	49.8	51.0	49.2	0.967
Formal education of household head (years)	7.4	7.4	7.4	0.025
Household size (number of persons)	7	7	6	1.711*
Total farm size (ha)	1.8	2.2	1.7	2.962***
Total crop area (ha)	1.5	1.7	1.4	1.593
Land allocated to banana (ha)	0.4	0.5	0.4	3.064***
Annual household income (UGX'000)	2504	2643	2427	1.189
Number of years known hybrids	5.4	5.3	5.4	1.103
Number of actors interact with	0.8	1.6	0.3	10.167***
Number of times interact with actors	4.8	10.9	1.3	8.513***
Number of years of membership to groups	5.5	5.2	5.7	0.511
Experience in banana research activities (years)	1.5	2.7	0.8	4.575***
Membership to groups (%)	67.4	75.9	62.6	0.034*
Receipt of information on HBVs in last 5 years (%)	40.9	81.6	18.1	0.000***
HHs involvement in banana research activities (%)	26.9	47.1	15.5	0.000***

***, ** and * indicate statistical significance level at 1%, 5% and 10%, respectively

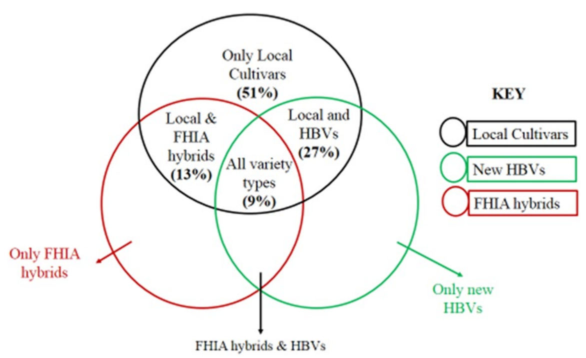

Fig. 2 The proportion of households using the different categories of cooking banana varieties (*n* = *242*)

compared to the non-adopters who owned an average of 1.7 ha and allocated 0.4 ha to bananas. In addition, the HBV adopters reported more linkages and interaction with other actors in the banana value chain especially research and extension, and had significantly more access to information about new HBVs. About 67% of the households had at least a family member belonging to a farmer group or association.

Figure 2 presents the different cooking banana varieties grown in the study area. These varieties were broadly classified into local cultivars, FHIA hybrids, and new HBVs. Results show that about 49% of the farmers grew at least one of the hybrids, in addition to local cultivars while 51% grew only local cultivars. In addition to local cultivars, 22% of the households grew FHIA hybrids while 36% grew the new HBVs. About 9% of the households grew all the varieties—the local cultivars, FHIA hybrids, and new HBVs. None of the households in the study grew only the hybrids. This is a clear indication that different banana varieties provide different attributes, which corroborates with Nalunga [31] who noted that farmers tend to select and grow the types of varieties that meet their diverse needs and farming objectives.

In addition, the source of planting materials for the HBVs adopters was also examined (Table 3). Results showed that the most important source of materials for HBVs initial planting was fellow farmers (62%), followed by a research institute (41%) and community leaders (39%). The high percentage of farmers reporting fellow farmers as a source of planting materials could be attributed to the farmer-to-farmer planting material distribution and on-farm demonstrations initiatives that were implemented by NARO since 2008. Despite the presence of government input subsidies through the National Agricultural Advisory Services (NAADS) for distribution of free banana planting materials, only 2.3% of the farmers reported NAADS as its source of HBV materials. This points to a need to interrogate the type of banana planting materials that are distributed to farmers.

However, access to planting materials does not always guarantee uptake. The adoption process for new varieties involves farmer evaluation of the different attributes

Table 3 Source of planting materials for new HBVs (% of cases)

Source	Overall (*n* = 87)	% response for each of the selected hybrid varieties						
		KABANA 6H (syn. 'M9')	(KABANA 7H (syn. 'M2')	M14	M17	M3	KABANA 5	Other hybrids
Fellow farmer	62.07	44.7	43.5	0.0	20.0	0.0	50.0	33.3
Research Institute	41.38	23.5	39.1	33.3	60.0	100	0.0	66.7
Community leader	39.08	20.0	4.3	0.0	20.0	0.0	12.5	0.0
NGO	12.64	7.1	8.7	33.3	0.0	0.0	25.0	0.0
Extension	4.60	3.5	0.0	33.3	0.0	0.0	0.0	0.0
NAADS	2.30	1.2	4.3	0.0	0.0	0.0	0.0	0.0
Input supply	1.15	0.0	0.0	0.0	0.0	0.0	12.5	0.0

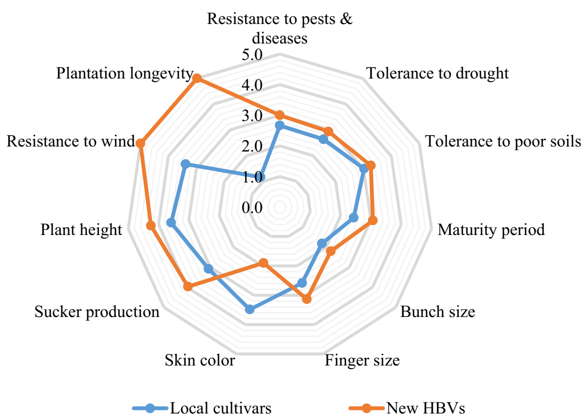

Fig. 3 Rating of production-related attributes across local cultivars and new HBVs

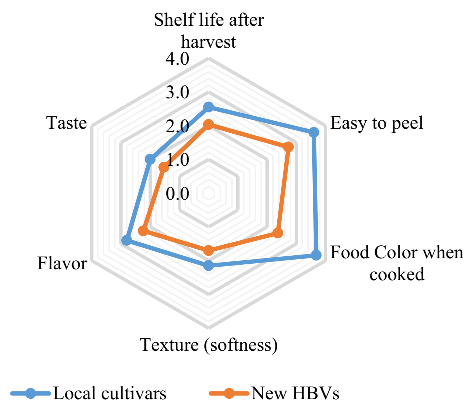

Fig. 4 Rating of processing and consumption-related attributes across local cultivars and new HBVs

using their own perceived criteria. Our initial analysis indicated that 61% of the farmers who were aware of the new HBVs were not growing them. Therefore, further analysis was done to identify farmers' assessment and preferences for attributes of the banana variety types grown.

Furthermore, the decision to grow different varieties points to the notion that farmers desire to obtain benefits such as high yields from hybrids and favorable consumption attributes from local cultivars [12]. Respondents were asked to score the production and consumption attributes that influenced their decisions to grow particular banana varieties. The production attributes scored included: resistance to pests and diseases, tolerance to drought and low soil fertility, maturity period, bunch size, fruit skin color, level of sucker production, plant height and resistance to wind. Consumption attributes included color and texture of the cooked food, its flavor and taste. Results presented in Figs. 3 and 4 showed that the new HBVs were scored highest in terms of production-related attributes, while local cultivars were rated superior to hybrids on consumption-related attributes.

The new HBVs were valued for their resistance to pests and diseases which also contributed to banana plantation longevity. These hybrids were also observed to be tolerant to poor soils and drought. The only production attribute where local cultivars rated superior to HBVs was fruit skin color, an attribute considered important for marketing bananas. Farmers prefer a deep green color for the outer skin of the fruit as opposed to the pale green skin color of HBVs. In terms of consumption attributes, the local cultivars were rated highest on all attributes. These results imply that a combination of production and consumption attributes derived from different varieties guide farmers' decisions in the selection of varieties to grow. For instance, the high yield potential of hybrids could assist farm households in achieving food security and having a surplus harvest to sell from either the hybrids or local cultivars. The study findings corroborate with Kikulwe [16] and Akankwasa [17] who found acceptability of banana hybrids being dependent on a combination of production and sensory attributes.

The role of socio-institutional factors and varietal attributes in the adoption of the new HBVs

Prior to estimating the Tobit model, diagnostic tests (multicollinearity, heteroskedasticity, endogeneity) were carried out and the model was found to be stable. The model results on the role of variety attributes and other factors in the adoption of HBVs are presented in Table 4. The model is significant at 1%, implying that it fits the data. The sex of a farmer, education of the farmer, household size, interaction with different banana actors, experience of growing HBVs, variety attributes and source of planting materials had significant influence on both the adoption and intensity of new HBVs (Table 4).

Sex of a farmer in charge of banana production activities had a positive influence on the adoption of HBVs. Female farmers were 12.4% more likely to adopt HBVs compared to male farmers. These are associated with 7.5 more HBVs mats compared to male farmers. This partly reflects the individual behavior of farmers and decision making issues in a household. Culturally in the studied districts, bananas are considered a women's crop due to strong inclinations to food security status of a household. Given the fact that food security is viewed by men as a women's role, women can put all their effort to ensure that food is on the table. The study finding is in line with Klapper and Parker [32] who found that women contribute up to 90% of Uganda's total food production. However, there is a likelihood that with increasing trends for value addition and agro-processing in banana, men will increasingly grow bananas for its cash income and profitability as observed with cassava in Malawi and Nigeria [33].

Contrary to some studies [15, 34], model estimates show that the education level of the farmer had a negative effect on the adoption of HBVs. Farmers with higher levels of education were 2.7% less likely to adopt HBVs. And if they happen to take on any HBV, their HBVs would be less by 1.6 mats. This corroborates findings of Akankwasa [20] who found the education level of a farmer to

Table 4 Determinants of HBVs adoption (dependent variable = number of HBVs mats)

Explanatory variables	Coefficient	Marginal effects	
		Probability of adoption	Intensity of adoption
Sex of farmer (1 = female)	25.81*(16.21)	0.124	7.545
Education of farmer	− 5.608** (2.245)	− 0.027	− 1.639
Total household size	6.073* (3.258)	0.029	1.775
Involvement in banana research activities^	1.865 (18.83)	0.009	0.545
Access to information^	3.529 (20.08)	0.017	1.032
Membership to farmer groups^	− 0.413 (19.07)	− 0.002	− 0.121
Household interaction with other actors	0.568* (0.295)	0.003	0.166
Experience with HBVs	− 6.005** (2.319)	− 0.029	− 1.755
Non-farm income	0.285 (0.772)	0.001	0.083
Land allocated to other crops[a]	4.021 (3.012)	0.019	1.175
Source of planting materials			
Research institutions	192.6*** (37.19)	0.922	56.295
Fellow farmer	131.5*** (28.81)	0.630	38.441
Community leader	157.7*** (35.33)	0.755	46.108
Other sources[b]	116.6*** (29.55)	0.558	34.080
Variety attributes			
Production traits related index[c]	40.90*** (10.07)	0.196	11.956
Agronomic traits related index[c]	− 7.545 (6.076)	− 0.036	− 2.206
Consumption attribute related index[c]	18.22*** (6.758)	0.087	5.326
Constant	− 160.8*** (39.94)		
Observations	242		
Pseudo R^2	0.1537		
Chi^2	0.0000		

^ Dummy variable; [a]logarithm; [b]other sources such as NGOs, Extension, NAADS, input suppliers; [c] indices; standard errors in parentheses; ***, ** and * indicate statistical significance level at 1%, 5% and 10%, respectively be negatively associated with the adoption of HBVs in Uganda. A possible explanation could be that educated farmers have the capacity to process information on HBVs and weigh the returns (food, income, safety) in comparison to the alternative local banana varieties, and hence may be hesitant to plant new banana hybrids for food since some farmers perceive hybrids to be genetically modified. However, planting more HBVs among the less educated farmers could be explained by the probability of such households having a big household size. Thus, such households may find the HBVs a better alternative to provide more food for household members.

Further, household size influenced the adoption of new HBVs. Households with a large number of household members were 2.9% more likely to adopt HBVs. These are associated with 1.8 more HBVs compared to a household with a small size. Such farm households may be more willing to take risks and allocate a portion of their land to try out new varieties. Household size may affect family labor supply for production. A larger household provides relatively cheaper labor if engaged in agricultural production and may produce more output in absolute terms to meet the food consumption requirements. This is in line with some adoption studies [12–14, 35, 36] that established that households with larger sizes were more likely to adopt new technology than those with smaller sizes. However, the high food consumption requirements for larger households may also drive them to adopt new HBVs due to their (the bananas) bigger bunch and finger size [20].

Intensity of interaction (measured by the number of times a banana farm household interacts with other actors especially those in agricultural research and extension) had a positive and significant influence on the intensity decision once the adoption decision had been made. Farm households that interacted more with other actors such as agricultural research, extension agents and traders among other actors had more HBVs mats than those who interacted with fewer or no other actors. A unit increase in the frequency of interaction with an actor increases the number of HBVs mats grown by a farmer by 0.3%. The findings corroborate previous research about actor interactions and adoption of agricultural technologies [37, 38]. This underscores the role played by research, extension and other actors in dissemination, promotion and commercialization of new technologies. Such linkages and interactions are important for the flow of information about variety attributes and utilization which enhances a farm household's knowledge and confidence in the new technology, therefore, promoting usage. Another possible explanation could be the fact that, usually, farm visits by actors mainly target households that have adopted and thus, the interactions provide useful linkages that serve to motivate a farm household to intensify the use of new technologies.

Surprisingly, the study found the number of years a farm household had known and grown the new HBVs to have a negative influence on the likelihood of adopting them. A one-year increase in a household's experience with HBVs reduced the expected likelihood of adoption by 2.9%. This could be attributed to the risk-averse behavior of farmers. As farmers observe undesirable attributes as they experiment with HBVs, they may be less able to undertake associated production risks. This corroborates with the descriptive results that indicated that 61% of the farmers were aware of new HBVs, but did not grow them. Farmers are in most cases less willing to continue growing new varieties that do not adequately meet their expectations as also stated by Ainembabazi and Mugisha [39].

From the results, the source of planting materials has a significant role in the adoption of HBVs, with the probability of adoption ranging from 55.8% to about 92.2% if the source of the material is a research institute. The sources of planting materials were associated with a higher intensity of 34 to 56 HBVs mats. Indeed, the descriptive results of this study indicated that fellow farmers and the research institute were the most important sources of planting materials. The results indicated that, over time, research institutes have developed capacity in providing genuine planting materials in which farmers have confidence. Furthermore, the significant influence of fellow farmers indicates that farmers tend to learn about new crops from peers cultivating the same crop [40]. Therefore, having neighbors growing HBVs can facilitate access to information and access to planting materials. Also, through social interactions that happen between farmers in the same location, farmers feel more secure that the new HBVs will not fail if they tried them out [41]. The non-adopters too learn and potentially adjust their choices to align with those of their neighbors [42].

As expected, the production and consumption attributes had positive influence on the adoption decision and adoption intensity. The likelihood of a farmer to adopt HBVs and plant more mats increased with the perceived importance of the associated traits of the HBVs. Specifically, HBVs with production attributes (tolerance to pests and diseases, drought-resistance, high yields) increase the likelihood of adoption of HBVs by 19.6% and adoption intensity by 12 HBV mats. A possible explanation could be that these hybrids fare better on the aforesaid traits than the local banana varieties and hence are favored over local varieties. This result is corroborated by Edmeades [43] who established that most farmers in central Uganda consider, in most cases, tolerance to marginal soils and drought-prevalent characteristics during banana varietal selection.

Consumption attributes (taste, texture, flavor, and color) increase the likelihood of adoption of HBVs by 8.7% and adoption intensity by 5.3 HBV mats. Farmers seemed to prefer new HBVs that combine both tolerance to major production constraints and with better consumption attributes. This is consistent with other studies [10, 11, 16, 44] that found variety attributes to be significantly associated with variety choice and number of HBVs mats. In particular, this validates the findings of a study on early-stage adoption of the hybrids by Akakwasa [20] who found that farmers were more likely to plant more mats of hybrid varieties with better sensory qualities such as soft food and yellow color when cooked. Beyond production-related attributes, farmers attach high importance to consumption attributes implying that breeding efforts should target producing varieties with superior production and desirable consumption traits. This underscores the importance of clearly understanding farmers' preferences when breeding new varieties. Farmers normally prefer new varieties that are comparable to their local varieties in the supply of desirable consumption attributes such as soft food, color when cooked, flavor and taste embedded in their culture [11, 12, 44]. Therefore, improvement of the current HBVs to supply better production and consumption attributes desirable to end-users would potentially enhance both adoption and adoption intensity decisions.

Conclusion and recommendations

The purpose of this paper was to establish the influence of variety attributes and other factors on the adoption of new HBVs among smallholder farm households in Central Uganda. Only 36% of the farm households sampled were using new HBVs. Descriptive statistics showed that HBVs had more preferred production-related traits than the local banana cultivar. Results from the Tobit model showed that the sex of a farmer, education, household size, interaction with different banana actors, the experience of growing HBVs, variety attributes and source of planting materials were the key drivers of the adoption of HBVs. The aforesaid factors had varying effects on the intensity of adoption of HBVs. The positive influence of interactions of households with actors on HBV adoption intensity signals the need to promote HBVs through multi-actor platforms which provide opportunities for formal and informal interactions between farmers and other actors. Such fora will not only serve to offer end-users with opportunities to access adequate information but also provide useful linkages that are important to support and guide the adoption and intensity of adoption decision processes. These findings suggest that breeders and development practitioners need to consider both HBVs attributes and social–institutional issues in the promotion of HBVs especially with respect to deliberately targeting smallholder farmers who are the majority producers of HBVs in Uganda.

This study has demonstrated that farmers in central Uganda perceive both production attributes and consumption traits to be important considerations in deciding to adopt and how much HBVs mats to plant. Considering the findings on the positive influence of sex of the farmer and the need to fully understand farmers' trait preferences highlights the importance of gender analysis in breeding priority setting for bananas. This reinforces the need for breeders to prioritize multiple traits with both men and women end-users right from the early stages of variety evaluation and selection. This will guide integration of both production and consumption (social/quality) related attributes in the breeding processes. Such a process will, however, require close collaboration between breeders and other disciplines especially those in the social sciences during the entire variety development process. Knowledge of the trait preferences by men and women actors along the banana value chain will be useful to inform breeders of the gender-specific preferences for banana varieties among end-users across agro-ecological zones and the trade-offs associated with local and hybrid bananas as a key to guide future banana breeding programs.

A key limitation of this study is that it focused on the region and districts were the HBVs where first tested. Although the results indicate that uptake of new HBVs is increasing, similar research in other agro-ecological zones is needed to understand the uptake levels and to document experiences of men and women farmers with the new HBVs. Such studies should also aim at establishing whether the observed increase in cultivation of hybrid banana varieties by the adopting households merely reflects farmers access to planting materials from project interventions or farmers' enhanced adaptive capacity for sustained use of HBVs.

Abbreviations

FHIA: *Fundación Hondureña de Investigación Agrícola* in Honduras (Honduras Foundation for Agricultural Research); *HBVs*: *Hybrid Banana Varieties*; KABANA: Kawanda Banana; NARO: National Agricultural Research Organisation; SSA: Sub-Saharan Africa.

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Authors' contributions

LNS conceived and designed the study, collected data and drafted the manuscript; HS reviewed the study tools and provided in-depth review of the manuscript; FBK provided technical guidance throughout the study process;

GMD provided technical guidance on the appropriate methodology during data collection and analysis; FN participated in analyzing data and manuscript preparation. All authors read and approved the final manuscript.

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Ethics approval and consent to participate
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Consent for publication
All authors agree and consent for the article to be published.

Competing interest
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