AfJARE
African Journal of Agricultural and Resource Economics Volume 16 Number 2 pages 155-168

DOI: 10.53936/afjare.2021.16(2).11

Preference for improved varietal attributes of Bambara groundnut among smallholder farmers in Ghana

Bright Owusu Asante*
Department of Agricultural Economics, Agribusiness and Extension, KNUST, Ghana. E-mail: boasante2@gmail.com

Richard Adabah
Department of Agricultural Economics, Agribusiness and Extension, KNUST, Ghana; CSIR-Crops Research Institute, Kumasi, Ghana. E-mail: radabah4u@gmail.com

Kennedy Agyeman
CSIR-Crops Research Institute, Kumasi, Ghana. E-mail: agyemanken@yahoo.com

Stephen John Ayeh
CSIR-Crops Research Institute, Kumasi, Ghana; Department of Agricultural Economics, Agribusiness and Extension, KNUST, Ghana. E-mail: sjohn.ayeh@gmail.com

Robert Aidoo
Department of Agricultural Economics, Agribusiness and Extension, KNUST, Ghana. E-mail: badubob@yahoo.co.uk

Daniel Afona
CSIR-Crops Research Institute, Kumasi, Ghana. E-mail: heavydash@yahoo.com

* Corresponding author

Abstract

This paper examines farmers' preferences for an improved Bambara groundnut variety, the key attributes desired, factors influencing preference, and the number of attributes desired by smallholder farmers in Ghana. Using data collected from 113 randomly selected households growing Bambara in the Wenchi and Nkoranza municipalities in southern Ghana, we estimate the factors influencing preference decisions and the intensity of the desired attributes using probit and Poisson regression models respectively. Preference for an improved Bambara variety is influenced by experience in farming, availability of extension services, credit access, membership of farmer-based organisations, plant type, seed colour, household size and yielding capacity. The attributes desired the most by farmers are high yielding capacity, high protein content, branched plant type and seeds that are dark or brown in colour. Furthermore, key factors influencing the number of attributes desired in an improved Bambara variety include the farmer's sex, education, years of experience in Bambara cultivation, household size, membership of farmer-based organisations and extension services. There is a need to consider these varietal attributes and the factors as integral to research and development efforts, as well as to the policy agenda, to enhance the adoption of improved Bambara varieties for increased productivity and incomes of smallholders in Ghana.

Key words: Bambara groundnut; desired attributes; preference; intensity

1. Introduction

Bambara groundnut (*Vigna subterranea* (L.) Verdc.) is a widely cultivated traditional African pulse of Western Nigerian and Eastern Sudanese origin (Pasquet 2003). Previously, it was cultivated mostly in the drier parts of sub-Saharan Africa (SSA), but has spread widely across tropical Africa (Brink &

Belay 2006). Berchie *et al*. (2010) identified Bambara groundnut as a subsistence crop cultivated mainly in tropical areas in Africa. Bambara is regarded as a subsistence crop due to its long cooking time, which has contributed to its low adoption rate among farmers (Tetteh & Opoku-Asiamah 1988).

In Ghana, Bambara is mostly cultivated in the northern and coastal areas, with a yield not exceeding 300 kg/ha (Berchie *et al*. 2010). Among the pulses, the crop is ranked third after groundnut and cowpea in terms of plant protein source in the diet of Africans in semi-arid areas (Omoikhoje 2008; Murevanhema & Jideani 2013). The pods of Bambara groundnut are about 1.5 cm in length, wrinkled and slightly oval, with one or two seeds per pod. Dried nuts have very hard seed coats. The seeds have different colours, including black, dark brown, red, white, cream, or a combination of these. Ripened pods are extracted from the soil, exposing the subterranean nuts during harvesting. Although the majority of consumers consume the nuts in the dried form, they can also be consumed in their fresh state as snacks (i.e. boiled or roasted before they are dried). Bambara seeds can also be processed into a very fine flour, which can be used to prepare a variety of dishes in Africa (Murevanhema & Jideani 2013). The ability of the crop to provide acceptable yields on marginal soils and under unfavourable environmental conditions has also been recognised (Azam-Ali *et al*. 2001; Hillocks *et al*. 2012). Bambara groundnut has been proven to be a tropical crop that is fairly drought tolerant, and thus also able to thrive in hot, dry regions with poor soil nutrients that are mostly regarded as marginal for other leguminous crops (Hillocks 2012; Muhammad *et al*. 2016; Khan *et al*. 2017).

There is extensive literature on the nutritional superiority of Bambara among other legumes (Brough & Azam-Ali 1992; Okpuzur 2010; Gqaleni 2014; Mubaiwa *et al*. 2018b; Temegne Nono *et al*. 2018; Oyeyinka *et al*. 2020; Hlanga *et al*. 2021). In addition to the ability of the crop to thrive under harsh environmental conditions, it also serves as an alternative to animal protein and a source of income for most rural dwellers and smallholder farmers (Hillocks *et al*. 2012). Bambara groundnut offers many opportunities, as it is an ideal crop for subsistence farming, is good for practising crop rotation, provides a cheap food source, and is a potential income booster when commercialised.

In spite of the significant performance associated with the cultivation of Bambara groundnut in the northern part of Ghana, coupled with its associated nutritional and food security benefits, minimal attention[1] has been paid to the crop by farmers and research, NGOs and donor agencies (Adzawla *et al*. 2015; Tan *et al*. 2020), its low patronage among smallholder farmers. Current research and development efforts have focused on nutritional quality, agronomic improvement, seed quality, etc. (Mubaiwa *et al*. 2018a; Mandizvo & Odindo 2019; Oyeyinka *et al*. 2020; Tan *et al*. 2020; Hlanga *et al*. 2021), with little effort being made to focus on the demand side to assess the preferences of consumers and, subsequently, the adoption of improved varieties. Accordingly, there have been minimal development efforts regarding the crop, resulting in very few improved varieties and hence low rates of adoption (Adzawla *et al*. 2016; Tan *et al*. 2020). Adzawla *et al*. (2015) reported that almost half of smallholder farmers (47.7%) did not adopt improved Bambara groundnut varieties and experienced difficulty in its cultivation, tedious harvesting, a low demand and lower yields as major factors influencing the low adoption rates. The lack of improved varieties and limited knowledge of farmers' preferred varietal attributes also contribute to the low adoption rates of food crops. For instance, varietal attributes such as pest resistance, ability to withstand drought, potential yield, ease of cooking, taste and the variety's ability to fetch a price premium influenced the adoption of pigeon pea varieties (Otieno 2010). Timu *et al*. (2014) also found that improved taste, drought tolerance, yield potential and ease of cooking were the major factors influencing the adoption of improved sorghum varieties. However, in addition to varietal qualities, other non-varietal characteristics have also influenced farmers' adoption decisions. These include group membership, education level of farmer and years of farming experience, which all positively influenced the probability of adoption

[1] This could be due to the underutilised nature of the crop and probably also because it is cultivated in small quantities; hence the potential of the crop in terms of its contribution to food security and nutrition was not identified until recently.

of improved pigeon pea varieties (Otieno 2010). Mutanyagwa *et al*. (2018) identified the factors that influence farmers' choice of improved maize seed varieties in Tanzania as household size and farm size, which significantly and positively contribute to farmers' choices for an improved maize variety. Ghimire and Huang (2015) also found education and extension services as important variables that positively affected the adoption of improved rice varieties among rural farm households in central Nepal. Subsequently, the adoption of improved varieties of Bambara has the potential to improve the food security and livelihoods of rural farmers. It therefore is imperative for breeders to carefully consider the varietal attributes desired by farmers.

This paper contributes to the limited empirical literature on Bambara groundnut by providing evidence of the determinants of farmers' preferences for improved varietal traits, as well as of factors influencing the number of attributes farmers consider when choosing an improved Bambara groundnut variety. Such information is very vital for researchers in developing demand-driven, improved Bambara groundnut varieties that will meet the needs of farmers, and hence enhance their adoption to increase the production and incomes of farmers. Unlike previous studies, which focused on nutritional superiority, this paper applies econometric approaches to understand the drivers of improved attributes and their effects on the preference for improved varieties. In addition, the findings also serve as critical entry points for development interventions aimed at enhancing Bambara groundnut production and consumption to reduce malnutrition in Ghana. This paper further provides researchers with the requisite knowledge of farmer-desired attributes for an improved Bambara groundnut variety. Such information can be incorporated into the breeding objectives of crop improvement programmes to ensure increased adoption and, ultimately, its implications for improving farmers' welfare.

The rest of the paper is structured as follows. The next section presents a review of the literature on factors influencing preferences for improved crop varieties. Section 2 presents the methodology used to achieve the objectives of the study. The results are presented in Section 4. Section 5 presents the discussion and Section 6 concludes.

2. Review of factors influencing preference for improved crop varieties

A number of factors have been found to influence farmers' preferences for or adoption of improved crop varieties. These include socioeconomic factors, institutional factors, farm-level factors, and attributes of the variety. Major socioeconomic factors influencing preference for an improved crop variety are the farmer's age, sex, education level and household size. The most common institutional factors are extension, awareness of the varieties, credit, membership of farmer-based organisations and access to non-governmental organisations and development projects. Farm-level factors include farm size, existing varieties cultivated, and access to fertilisers and other complementary technologies.

Access to extension services empowers farmers with technological skills and access to the required information on adopting new varieties (Paudel & Matsuoka 2008). According to Kabunga *et al.* (2012), farmer contacts with extension agents can never be underrated as far as the adoption of new knowledge is concerned. Agricultural extension services play a significant role in the period from awareness to the adoption stage of new varieties. Katung and Akankwasa (2010) found that farmer-based groups increase the likelihood that members will adopt a new technology as a result of education and social interaction with other members. Gender has also been found to have an influence on preferences for new technologies among farmers. According to Bruce *et al*. (2014), the adaptation to new agricultural technology, especially improved varieties, by men is easier relative than by their female counterparts. Furthermore, farmers' level of education contributes substantially to the adoption process because it has been proven that the higher the educational level, the easier it is to adapt to the use of improved varieties of seeds (Kabunga *et al*. 2012; Bruce *et al*. 2014). Similarly, Patel *et al*. (2004) reported that, more often than not, farmers prefer improved varieties due to their high yield, quality and easy marketability. Access to credit has also been found to stimulate preferences for improved crop varieties or technologies because of its ability to promote the adoption of risky technologies through the relaxation of the liquidity constraint, as well as by boosting households' risk-bearing ability (Mwangi & Kariuki 2015).

3. Materials and methods

3.1 Study area

Data for this paper was collected from farmers in the forest savanna transition agroecological zone of Ghana. This zone is characterised by a bimodal rainfall pattern and hence presents a favourable environment for the production of a number of food crops, including Bambara groundnut. One of the significant growing areas for Bambara groundnut in this zone is the Brong Ahafo region, and specifically the Wenchi Municipality and Nkoranza South District. Wenchi is located in the western part of the Brong Ahafo region. It is the largest among the 22 districts in the region, and the capital of the Wenchi Municipal. Nkoranza South district is also located in the mid-north of Ghana, with Nkoranza as its capital. The majority of the inhabitants in both areas depend on agriculture as their major source of livelihood. Both qualitative and quantitative data was used for the study, including focus group discussions and key informant interviews. This allowed for community-based information relating to Bambara groundnut production to be gathered.

3.2 Sampling and data

A multi-stage sampling technique was employed in this study. In the first stage, the Wenchi Municipality and Nkoranza South districts were purposively selected based on the high production of Bambara groundnut in these areas. From each district/municipality, five Bambara groundnut-growing communities were also purposively selected in the second stage. Finally, from each community, 10 Bambara groundnut-producing households were randomly selected from a list of Bambara groundnut-producing households obtained from the extension officers of the Ministry of Food and Agriculture. However, due to non-response, a total of 113 Bambara groundnut farmers were involved in the study, consisting of 75 farmers who preferred and 38 farmers who did not prefer the improved Bambara variety. The data was collected through individual interviews using structured questionnaires. The data collected included information on the demographics of the farmers, and farm-level, institutional and varietal characteristics of Bambara groundnut.

3.3 Analytical framework

The data was analysed using Stata software version 16. Descriptive statistics such as graphs and tables were used to summarise the sociodemographic characteristics and the farmers' desired attributes in an improved Bambara groundnut variety. The factors that influence farmers' preferences for an improved Bambara groundnut variety and the number of varietal traits preferred by farmers were analysed using the binary probit and Poisson regression models respectively.

3.3.1 Examining farmers' preferences for improved Bambara groundnut varieties

Following Greene (2003) and Becerril and Abdulai (2010), the decision to prefer an improved Bambara variety is grounded in the random utility framework (McFadden 1984). Thus, let us represent the utility of preferring an improved Bambara variety by (U_{iP}) and the utility of not preferring an improved variety by (U_{iN}). It follows that a randomly selected farmer will prefer an improved variety if $D^{*} = (U_{iP}) > (U_{iN})$, where D^{*} denotes the difference in utility of preferring an improved variety. However, the two utilities cannot be observed, but can be expressed using a latent variable, as specified below:

$$D_i^* = X_i\alpha + \varepsilon_i \text{ and } D_i = \begin{cases} 1 & \text{if } D_i^* > 0 \\ 0 & \text{otherwise} \end{cases}, \tag{1}$$

where D is a binary variable representing the preference for an improved Bambara variety; $D^* = 1$ if the farmer prefers an improved variety, and $D = 0$ otherwise. α is a vector of parameters to be estimated, X is a vector of demographic factors, farm-level factors, crop-related factors and consumer-dependent attributes, and ε is the random error term. Following Greene (2011), the probit model for estimating equation (1) is specified as:

$$Prob(Y_i = 1|X) = \int_{-\infty}^{X'\alpha} \phi(t)\, dt = \Phi(X'\alpha), \tag{2}$$

where the function $\Phi(X'\alpha)$ denotes the probability of preferring an improved Bambara variety, which follows a standard normal distribution. The empirical model for estimating farmers' preferences for improved varieties is thus specified as:

$$P(Y_i = 1|X) = \eta + X_i\alpha + \varepsilon_i, \tag{3}$$

where Y_i is a binary variable denoting preference for an improved Bambara variety and X_i is a vector of demographic, farm-level, crop-related factors and consumer-dependent attributes. α are parameters to be estimated, and ε_i is a random error term.

3.3.2 Examining the intensity of preferences for improved Bambara groundnut varieties

To examine the factors affecting the intensity of farmers' preferences for an improved Bambara variety, the Poisson regression model was employed following Awuni *et al*. (2018). This model has been applied extensively in examining the possibility of predicting the probabilities of the occurrence of an event (Ramirez & Shultz 2000; Rahelizatovo & Gillespie 2004; Kim *et al*. 2005). Subsequently, we used the Poisson regression model to examine the factors affecting the intensity of farmers' preferences for an improved Bambara variety. The dependent variable (y) is a count of the number of attributes a Bambara farmer desires in an improved variety; that is, $y = 0, 1, 2, 3, \ldots, N$.

Y is considered the response variable; hence, its probability density function can be expressed as:

$$f(y_1 | x_i) = P(Y_i = y_i) = \frac{e^{\lambda}\lambda^{y}}{y!}, \qquad y = 0,1.2.3....., \text{y}, \tag{4}$$

where Y_1 is the number of attributes chosen by a farmer, x_i are the determinants of improved variety preference, and λ is the mean (and variance) of Y in the probability density function in equation (4). That is, $E(Y) = \text{var}(Y) = \lambda$. Therefore, the parameter λ_i usually takes a log linear functional form defined as $\ln\lambda_i = x_i^{'}\beta$. Hence, the log likelihood function for the Poisson regression model is given as:

$$\ln L = \sum_{i=1}^{n}\left[-\lambda_i + y_i(x_i^{'}\beta) - \ln y_i!\right]$$

From equation (4), the empirical model can be specified as:

$$E(Y_i = 1|X) = \emptyset + X_i\partial + \delta_i,$$

where Y_i is the number of attributes preferred in an improved Bambara variety and X_i is a vector of demographic, farm-level, crop-related factors and consumer-dependent attributes. δ_i is a random error term.

4. Results

4.1 Farmer characteristics and preference decisions

Table 1 below presents the characteristics of the farmers' summary statistics relating to the variables used in the paper. The *t*-test statistics displayed in Table 1 show a statistical difference in means for variables between farmers who prefer and farmers who do not prefer an improved Bambara variety. On average, the number of years of schooling was statistically different between farmers who preferred an improved variety and those who did not. Farmers who preferred an improved variety had an average of 45 years of experience in farming, whereas farmers who did not prefer an improved variety had a mean of 36 years of experience. Extension contact with farmers was statistically different between the two groups of farmers and was significant. Extension services are one of the major ways in which farmers gain access to first-hand information on improved crop varieties and other improved technologies. The results further show a statistical difference in means among the farmers who preferred the improved variety and those who did not, at the 1% level of significance. Furthermore, both the variety with the ability to fix higher amounts of nitrogen and the variety with the potential to produce a high yield had differences in their means, which were statistically significant at 1% and 5% respectively.

Table 1: Summary statistics of farmers' preferences for a improved Bambara variety

Variable	Improved variety (N = 75)		No improved variety (N = 38)		Pooled (N = 113)		T-stat[æ]
	Mean	SD	Mean	SD	Mean	SD	
Sex (male = 1)	0.37	0.48	0.35	0.087	0.372	0.485	-0.226
Education (years)	5.3	0.5	3.4	0.8	4.8	0.4	-2.02**
Experience (years)	45.0	1.8	36.3	2.4	42.5	1.5	-2.79***
Off-farm income (%)	0.463	0.502	0.452	0.506	0.460	0.501	-0.111
Farm size (acre)	8.488	0.884	7.274	1.105	8.155	0.709	-0.76
Household size (N)	2.841	0.268	1.710	0.168	2.531	0.205	-2.52**
Extension contacts per year	22.0	2.6	2.8	0.6	16.8	2.0	-4.58***
Credit use (%)	0.268	0.049	0.194	0.072	0.248	0.041	-0.82
Variety traits							
Drought resistance (%)	0.976	0.017	0.903	0.054	0.956	0.019	-1.67*
Erect orientation (%)	0.500	0.056	0.355	0.087	0.460	0.047	-1.38
Seed colour (%)	0.561	0.055	0.258	0.080	0.478	0.047	-2.96***
High yielding (%)	0.963	0.021	0.839	0.067	0.929	0.024	-2.34**
Fix nitrogen (%)	0.878	0.036	0.613	0.089	0.805	0.037	-3.29***

[æ] The asterisks *, ** and *** denote that the differences in the means of the variables are significant at the 10%, 5% and 1% level respectively across the preferences for improved and local varieties. SD is the standard deviation.

The drought-resistant attribute was also statistically significant at 1%. The mean household size of farmers who preferred an improved variety was 2.8, whereas those who preferred the local variety had a mean household size of 1.7. The statistical difference in mean was significant at 5%.

4.2 Factors influencing farmers preference for improved Bambara varieties

Table 2 shows the results of a probit regression model explaining the factors that influence farmers' preferences for an improved Bambara variety. The R^2 of 0.6491 depicts a 65% level of accuracy that the underlying factors in the model influence farmers' preferences for an improved Bambara variety. The number of years of farming had a positive relationship with an improved variable at the 1% level of significance. Farmers who had contact with extension officers and those who belonged to farmer-based organisations also correlated positively with the preference for an improved variety, and showed statistical differences at the 5% and 1% level of significance respectively.

Table 2: Results of probit regression on factors influencing farmers' preferences for an improved Bambara variety

Variable	Coefficient[æ]	SE	ME	t-stat
Sex	0.423	0.569	0.122	0.743
Education	0.100	0.059	0.032	1.695
Farming experience	0.067***	0.023	0.021	2.913
Extension contacts	0.107**	0.043	0.034	2.488
Credit	0.774***	0.064	0.034	12.094
FBO membership	0.491***	0.060	0.046	8.183
Drought	0.523	1.441	0.028	0.363
Branched	0.630***	0.060	0.067	10.500
Seed colour	0.335***	0.049	0.050	6.837
Farm size	0.018	0.044	0.006	0.409
Household size	0.655***	0.230	0.021	2.848
High yielding	0.090**	0.045	0.694	2.000
High N-fixing ability	0.341	0.729	0.014	0.468
Constant	-0.767	0.895		-0.857
LR	83.6000			
Pseudo R^2	0.6491			
Predicted preference	0.987783			

[æ] The asterisks ** and *** denote that the differences in the means of the variables are significant at the 5% and 1% level respectively across the preferences for improved and local varieties.

Access to credit also correlated positively with farmers' preferences for an improved variety at the 1% level of significance. Furthermore, there was a statistical difference between the colour of the improved variety and the decision to adopt it – also at the 1% level of significance. Plant orientation was also found to positively and significantly influence farmers' preferences for an improved variety at the 1% level of significance. The yielding capacity of the improved Bambara variety at the 5% level of significance positively satisfied the probability of a new variety being preferred by farmers. At the 1% significance level, household size was statistically different among those who preferred the improved variety and those who did not.

4.3 Attributes desired in an improved Bambara groundnut variety

Figures 1 and 2 illustrate the various attributes farmers desire in an improved variety. The attributes considered were drought tolerance, disease resistance, high nitrogen fixation, high carbon and protein content, high-yielding capacity, erect and branched plant, easy to harvest and ease of cooking.

Figure 1 shows that all the farmers desired to have an improved Bambara variety with the ability to produce high yields and also a variety with high protein content. Ninety-five percent of the farmers also expressed their preferences for Bambara groundnut with the following attributes: drought resistant, disease tolerant, high nitrogen-fixing ability, high carbohydrate content, ease in harvesting and easy to cook. It can be concluded that these attributes are of high concern to farmers with regard to an improved variety, hence an improved Bambara groundnut variety should be characterised by these attributes. Fifty-four percent of the farmers indicated their disinterest in an improved variety that was erect and 88% of the farmers also expressed their desire for a branched variety.

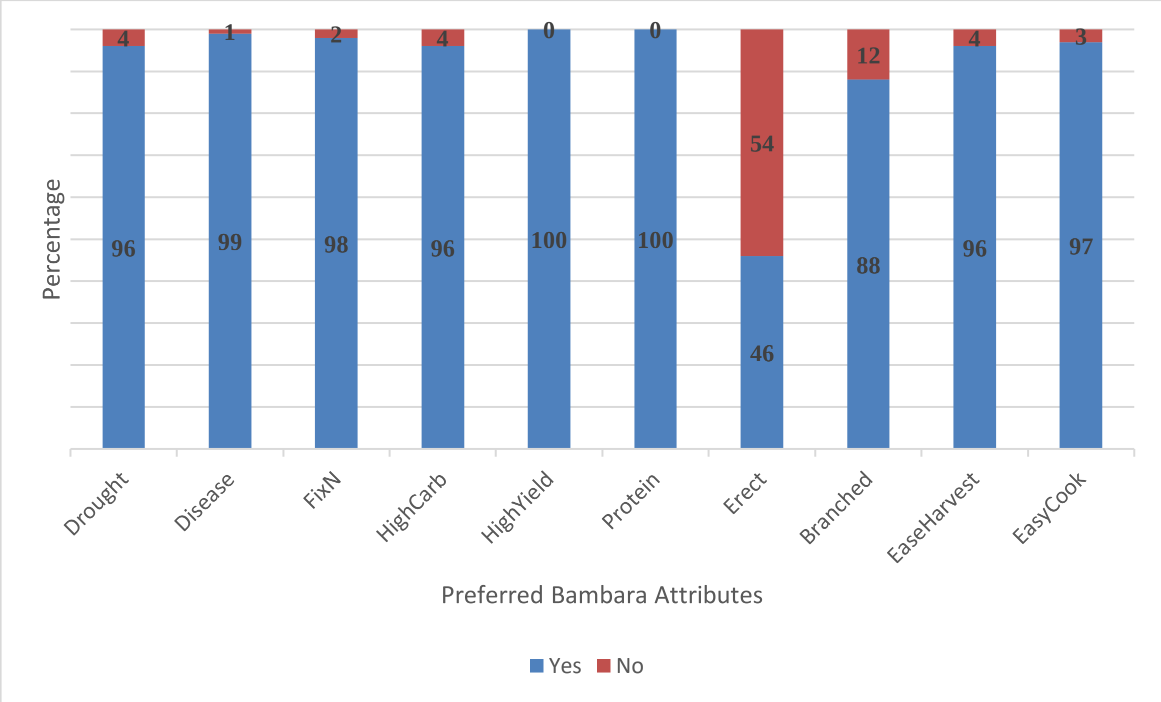

Figure 1: Desired attributes of an improved Bambara groundnut variety

4.4 Desired bean colour of Bambara groundnut

The colour of Bambara groundnut is another important characteristic to be considered in the adoption of an improved variety. Figure 2 presents the bean colour preferred by the sampled farmers. The results show a higher preference for the dark and brown beans in an improved variety, followed by light-coloured beans, with white, red and cream in that order. Light-coloured beans are found to have high germination rates and the thickest seed coats (Mandizvo & Odindo 2019), although they also are associated with low yields (Odindo 2007; Mabhaudhi 2012).

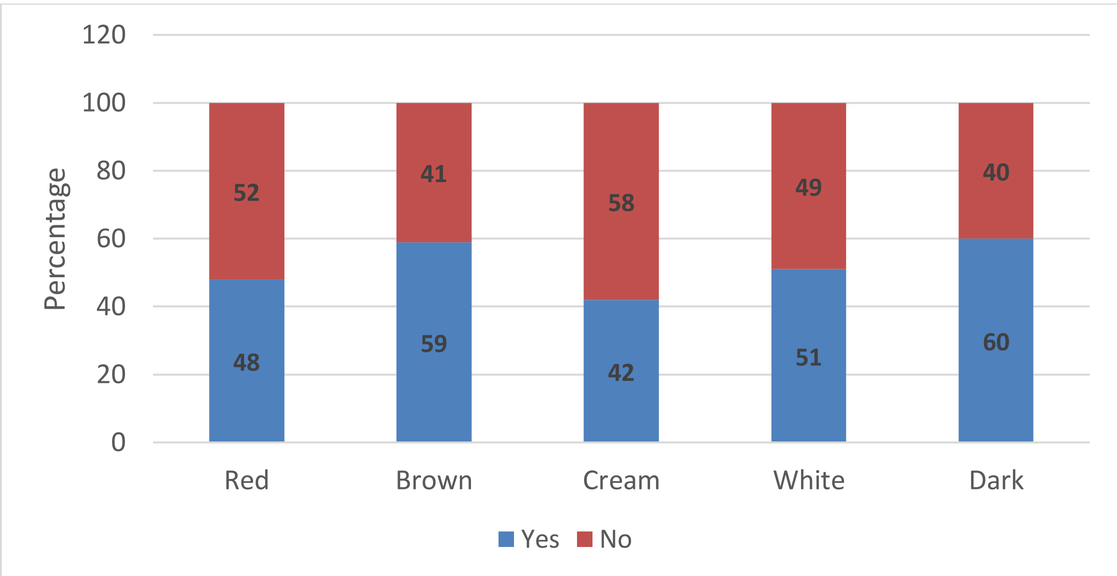

Figure 2: Desired colour of an improved Bambara groundnut variety

4.5 Factors influencing the number of attributes farmers are expecting in the new variety

Table 3 shows the Poisson regression results of the factors influencing the number of attributes a farmer expects in an improved Bambara variety. The results show that significant factors that influence the number of traits desired in an improved Bambara variety include the farmer's sex, Bambara experience, education, household size, farm size, mounding, FBO membership and extension contacts.

Table 3: Poisson regression estimates of the number of attributes desired by farmers in an improved Bambara groundnut variety.

Variable	Coefficient[æ]	IRR	Robust SE	ME
Sex	0.308***	1.361	0.0973	1.738
Education	0.021***	0.979	0.0069	0.116
Bambara experience	0.050***	0.999	0.004	-0.028
Household size	0.079**	0.924	0.0380	-0.435
Farm size	0.017***	0.983	0.0059	-0.094
Mounds	0.190***	1.209	0.022	0.991
Market distance	0.001	1.001	0.003	0.035
FBO	0.211**	1.021	0.097	0.116
Credit	0.072	1.074	0.104	0.398
Extension contact	0.024***	1.002	0.003	0.013
Output	0.271	1.312	0.208	1.324
Constant	1.512	4.535	0.270	
N	133			
Pseudo R^2	0.0643			
Hosmer–Lemeshaw test	Prob > chi^2: = 0.9953			

æ The asterisks, ** and ***, denote that the differences in the means of the variables are significant at the 5% and 1% levels respectively across the preferences for improved and local varieties. IRR = incident rate ratio; SE = standard error; ME = marginal effects

The sex variable positively and significantly influences the number of attributes desired in an improved Bambara variety. This implies that male farmers tend to prefer more improved varietal traits in an improved variety compared to female farmers. Number of years of education also had a positive relationship with number of expected attributes and as statistically significant, suggesting that the more years of schooling a person has, the more likely he/she will be to desire more varietal traits.

Being enlightened through formal education enhances the farmer's ability to evaluate the implications of varietal attributes. Similarly, years of cultivation of the crop was statistically significant at the 1% level. Experienced farmers are a rich source of information on varietal traits, and hence are more likely to desire more attributes in an improved variety based on their objectives. Furthermore, household size and farm size had positive effects on the number of attributes required in an improved Bambara variety, while FBO membership and extension interactions had positive influences on the number of attributes desired in an improved Bambara variety. Plating on mounds also influenced the number of desired varietal traits in an improved Bambara variety.

5. Discussion

5.1 Preference for improved Bambara varieties

The results from Table 2 indicate that the preference for an improved Bambara variety was influenced by experience in farming, extension contacts, credit access, FBO membership, plant orientation, colour of seed, household size and yielding capacity.

5.2 Socio-demographic factors and preference for improved Bambara varieties

Experience in Bambara farming has the potential to influence farmers' preferences for an improved variety of Bambara. Experienced farmers are able to make informed decisions regarding the relevance of specific traits as well as the number of traits preferred in an improved variety. The positive influences of extension imply that the more contacts a farmer has with extension services, the higher the probability that the farmer would prefer more attributes in an improved variety. Extension contacts through farmer field schools, training sessions and access to extension workers have been found to positively influence adoption decisions (Becerril & Abdulai 2010; Awotide *et al*. 2012). Similarly, belonging to a farmer-based organisation (FBO) is able to influence farmers' preferences for improved varieties. This finding is also in agreement with Katung and Akankwasa (2010), who revealed that belonging to a farmer-based group increased the likelihood that farmers would prefer a new technology on the basis of training and social networks with other members. The positive effect of household size on the number of traits preferred in an improved Bambara variety can be attributed to the fact that, with a large household size, farmers are able to allocate an adequate amount of labour to try new technologies, which makes it relatively cheaper for them. Household size has been found to influence the adoption and the effect of improved crop technologies (Adekambi *et al*. 2009; Kassie *et al*. 2010; Awotide *et al*. 2011).

5.3 Varietal traits and farmers' preferences for improved Bambara varieties

Figure 1 reveals that the most desired attributes farmers prefer in an improved variety are high yielding capacity and high protein content. These two attributes can therefore be considered as the most important attributes for farmers, and therefore in developing improved Bambara groundnut varieties, researchers need to consider high yielding and high protein content to enhance their uptake. This finding is consistent with Patel *et al*. (2004), who reported that, more often than not, farmers preferred improved varieties due to their high yielding characteristic. However, with regard to plant orientation, the farmers preferred a branched variety against erect varieties. Furthermore, the improved variety should have either dark or brown nuts to boost preference and thus the adoption of the new variety.

The results further show that the number of attributes a farmer expects in a new variety is influenced by the farmer's sex, educational level, experience in Bambara cultivation, farm size, planting technique, FBO membership and extension contact. The results also show that the number of attributes preferred in an improved Bambara variety is higher for men than for women farmers. The results further indicate that the higher the number of years of formal education attained by a farmer, the higher the number of attributes a farmer expects in an improved Bambara variety. Educated farmers tend to be more informed with regard to the qualities and benefits of an innovation. Farmers who cultivated larger farms expected a higher number of attributes with regard to an improved variety. Similarly, farmers with larger household sizes expected more attributes. For instance, an increase in household size and farm size are expected to result in an increase in the number of attributes a farmer expects in new variety. Farmers who had extension contacts and those who belonged to an FBO preferred an improved variety to have more attributes due to the training and farmer education the obtained through interactions with extension services as well as other group-related activities. Farmers who are more experienced in the cultivation of Bambara are likely to be more knowledgeable about the cultivation of the crop, hence it is not surprising that they would expect more attributes to be associated with an improved variety.

6. Conclusion and policy recommendations

This paper examined farmers' preferences for varietal attributes in an improved Bambara groundnut in Ghana. The results show that farmers' years of experience in Bambara groundnut production, access to credit, contact with extension and household size are the major factors that influence farmers' preferences for an improved Bambara variety. Crop-specific attributes include high yielding capacity, plant orientation, ease in harvesting and dark brown seed colour. It is necessary that research and development, as well as policy makers, pay more attention to these factors in the development of improved varieties, as well as in strategies for improving their adoption among smallholder farmers in Ghana.

The result also reveals that the farmer's sex, education, experience in Bambara cultivation, farm size, planting technique, FBO membership and extension contact influence the intensity of the desired attributes in an improved Bambara variety. Our findings further show the significance of climate-smart attributes, such as tolerance to drought, disease and pests and high nitrogen-fixing ability, as important varietal traits in an improved Bambara variety. In the wake of the prevailing trend of climate change, it is paramount for such climate smart attributes to be incorporated into existing breeding objectives for improved Bambara to boost the climate resilience and increase the incomes of farmers.

The findings also reveal the significance of other consumer-driven attributes that have traditionally been ignored in most adoption and preference studies, such as high carbohydrate content, colour of seed, and ease of cooking. Given the significance of the role of consumers in food value chains and their role in the ultimate acceptability of an improved technology or variety, it is recommended that such attributes be factored into breeding goals to achieved the desired adoption targets for the increased incomes and improved livelihoods of smallholder farmers in Ghana. Finally, to enhance the number of attributes that farmers desire to see in an improved variety, strategies should target farmers with large household sizes who are members of FBOs and who have contacts with extension services.

Acknowledgements

This research was funded by the International Treaty on Plant Genetic Resources for Africa (IT-PGRFA) in partnership with the Crops for the Future Research Centre (CFFRC) in Malaysia. We would also like to express our appreciation to the technical staff of the CSIR-Crops Research Institute, who assisted in data collection. We are grateful to the farmers in the Wenchi and Nkoranza Municipalities, for their time and patience in contributing to the data collection.

References

Adekambi SA, Diagne A, Simtowe F & Biaou G, 2009. The impact of agricultural technology adoption on poverty: The case of NERICA rice varieties in Benin. Paper presented at the International Association of Agricultural Economists (IAAE) Conference, 16–22 August, Beijing, China.

Adzawla W, Donkoh SA & George N, 2016. Adoption of Bambara groundnut production and its effects on farmers' welfare in Northern Ghana. African Journal of Agricultural Research 11(7): 583–94.

Adzawla W, Donkoh SA, Nyarko G, O'Reilly P, Olayide OE & Awai PE, 2015. Technical efficiency of Bambara groundnut production in northern Ghana. UDS International Journal of Development 2(2): 37–49.

Awotide BA, Awoyemi TT, Diagne A & Ojehomon VT, 2011. Impact of access to subsidized certified improved rice seed on income: Evidence from rice farming households in Nigeria. OIDA International Journal of Sustainable Development 2(12): 43–60.

Awotide BA, Diagne A & Omonona BT, 2012. Impact of improved agricultural technology adoption on sustainable rice productivity and rural farmers' welfare in Nigeria: A local average treatment effect (LATE) technique. Paper presented at the African Economic Conference October, 30 October–2 November, Kigali, Rwanda.

Awuni JA, Azumah SB & Donkoh SA, 2018. Drivers of adoption intensity of improved agricultural technologies among rice farmers: Evidence from northern Ghana. Review of Agricultural and Applied Economics (RAAE) 21(2): 48–57.

Azam-Ali SN, Sesay A, Karikari SK, Massawe FJ, Aguilar-Manjarrez J, Brennan M & Hampson KJ, 2001. Assessing the potential of an underutilized crop – A case study using Bambara groundnut. Experimental Agriculture 37: 433–72

Becerril J & Abdulai A, 2010). The impact of improved maize varieties on poverty in Mexico: A propensity score-matching approach. World Development 38(7): 1024–35.

Berchie JN, Adu-Dapaah HK, Dankyi AA, Plahar WA, Nelson-Quartey F, Haleegoah J, Asafu-Agyei JN & Addo JK, 2010. Practices and constraints in Bambara groundnut production, marketing and consumption in the Brong Ahafo and Upper-East regions of Ghana. Journal of Agronomy 9(3): 111–8.

Brink M & Beley G, 2006. Plant resources of tropical Africa 1: Cereals and pulses. Wageningen, Netherlands; PROTA Foundation / Leiden, Netherlands: Backhuys Publications / Wageningen, Netherlands: CTA.

Brough SH & Azam-Ali SN, 1992. The effect of soil moisture on the proximate composition of Bambara groundnut (*Vigna subterranea* (L) Verdc.). Journal of Science of Food Agriculture 60: 197–203.

Bruce AKK, Donkoh SA & Ayamga M, 2014. Improved rice variety adoption and its effects on farmers' output in Ghana. Journal of Development and Agricultural Economics 6(6): 242–8.

Ghimire R & Huang WC, 2015. Household wealth and adoption of improved maize varieties in Nepal: A double-hurdle approach. Food Security 7(6): 1231–35.

Gqaleni P, 2014. Nutritional value of Bambara groundnut (*Vigna subterranea* (L.) Verdc.): A human and animal perspective. Doctoral dissertation, University of KwaZulu-Natal, Pietermaritzburg, South Africa.

Greene WH, 2003. Econometric analysis. Chennai: Pearson Education India.

Hillocks RJ, Bennett C & Mponda OM, 2012. Bambara nut: A review of utilization, market potential and crop improvement. African Crop Science Journal 20(1): 1–16.

Hlanga NC, Modi AT & Mathew I, 2021. Evaluating nutritional content among Bambara groundnut lines. Journal of Food Composition and Analysis 102: 104053.

Kabunga N, Dubois T & Qaim M, 2012. Yield effects of tissue culture bananas in Kenya: Accounting for selection bias and the role of complementary inputs. Journal of Agricultural Economics 63(2): 444–64.

Kassie M, Shiferaw B & Muricho G, 2010. Adoption and impact of improved groundnut varieties on rural poverty: Evidence from rural Uganda. Discussion Paper No. dp-10-11-eft, Resources for the Future, Environment for Development, Gothenburg, Sweden.

Katung E & Akankwasa K, 2010. Community-based organizations and their effect on the adoption of agricultural technologies in Uganda: A study of banana (*Musa* spp.) pest management technology. Acta Horticulturae 879: 719–26.

Khan F, Chai HH, Ajmera I, Hodgman C, Mayes S & Lu C, 2017. A transcriptomic comparison of two Bambara groundnut landraces under dehydration stress. Genes 8(4): 121.

Kim SA, Gillespie JM & Paudel KP, 2005. Count data analysis of the adoption of best management practices in beef cattle production. Paper presented at the Southern Agricultural Economics Association Annual Meeting, 5–9 February, Little Rock, Arkansas, USA.

Mabhaudhi T, 2012. Drought tolerance and water-use of selected South African landraces of taro (*Colocasia esculenta* L. Schott) and Bambara groundnut (*Vigna subterranea* L. Verdc.). PhD thesis, University of KwaZulu-Natal, Pietermaritzburg, South Africa.

Mandizvo T & Odindo AO, 2019. Seed mineral reserves and vigour of Bambara groundnut (*Vigna subterranea* L.) landraces differing in seed coat colour. Heliyon 5(5): e01635.

McFadden DL, 1984. Econometric analysis of qualitative response models. In Griliches Z & Intriligator MD (eds.), Handbook of econometrics, Vol 2. Amsterdam: North Holland Publishing.

Mubaiwa J, Fogliano V, Chidewe C & Linnemann AR, 2018a. Bambara groundnut (*Vigna subterranea* (L.) Verdc.) flour: A functional ingredient to favour the use of an unexploited sustainable protein source. PloS One 13(10): e0205776.

Mubaiwa J, Fogliano V, Chidewe C, Bakker EJ & Linnemann AR, 2018b. Utilization of Bambara groundnut (*Vigna subterranea* (L.) Verdc.) for sustainable food and nutrition security in semi-arid regions of Zimbabwe. PloS One 13(10): e0204817. https://doi.org/10.1371/journal.pone.0204817

Muhammad YY, Mayes S & Massawe F, 2016. Effects of short-term water deficit stress on physiological characteristics of Bambara groundnut (*Vigna subterranea* (L.) Verdc.). South African Journal of Plant and Soil 33(1): 51–8.

Murevanhema YY & Jideani VA, 2013. Potential of Bambara groundnut (*Vigna subterranea* (L.) Verdc) milk as a probiotic beverage – A review. Critical Reviews in Food Science and Nutrition 53(9): 954–67.

Mutanyagwa AP, Isinika A & Kaliba AR, 2018. The factors influencing farmers' choice of improved maize seed varieties in Tanzania. International Journal of Scientific Research and Management 6(4): 55–63.

Mwangi M & Kariuki S, 2015. Factors determining adoption of new agricultural technology by smallholder farmers in developing countries. Journal of Economics and Sustainable Development 6(5): 208–16.

Odindo AO, 2007. Cowpea seed quality in response to planting site. PhD thesis, University of KwaZulu-Natal, Pietermaritzburg, South Africa.

Okpuzur J, Ogbunugafor HA, Okapor U & Sofidiya MO, 2010. Identification of protein types in Bambara groundnut seeds: Perspectives for dietary protein supply in developing countries. EXCLI Journal 9: 17–28.

Omoikhoje SO, 2008. Assessment of the nutritive value of Bambara nut as influenced by cooking time. Livestock Research for Rural Development 20(4): Article no. 55.

Otieno ZA, 2010. The role of varietal traits in the adoption of improved pigeon pea varieties in Kenya: The case of Taita District. MSc thesis, Department of Agricultural Economics, University of Nairobi, Kenya.

Oyeyinka SA, Ajisafe AO, Akintayo OA, Iyiola OA, Oyeyinka AT, Olatunde SJ & Patel N, 2020. Effect of microwave treatment on cooking time, colour, sensory and nutritional properties of Bambara groundnut (*Vigna subterranea*). Hrvatski časopis za prehrambenu tehnologiju, biotehnologiju i nutricionizam 15(1–2): 11–6.

Pasquet RS, 2003. Bambara groundnut and cowpea gene-pool organization and domestication. In Proceedings of the International Bambara Groundnut Symposium. Gaborone, Botswana: Botswana College of Agriculture.

Patel VT, Prajapati MR, Joshi KM & Patel JC, 2004. Potato cultivation technologies as perceived by potato growers of Gujarat. Potato Journal 31: 195–9.

Paudel P & Matsuoka A, 2008. Factors influencing adoption of improved maize varieties in Nepal: A case study of Chitwan District. Australian Journal of Basic and Applied Sciences 2(4): 823–34.

Rahelizatovo NC & Gillespie JM, 2004. The adoption of best-management practices by Louisiana dairy producers. Journal of Agricultural and Applied Economics 36(1): 229–40.

Ramirez OA & Shultz SD, 2000. Poisson count models to explain the adoption of agricultural and natural resource management technologies by small farmers in Central American countries. Journal of Agricultural and Applied Economics 32(1): 21–33.

Tan XL, Azam-Ali S, Goh EV, Mustafa MA, Chai HH, Ho WK, Mayes S, Mabhaudhi T, Azam-Ali S & Massawe F, 2020. Bambara groundnut: An underutilized leguminous crop for global food security and nutrition. Frontiers in Nutrition 7: 601496.

Temegne Nono C, Foh TDN, Taffouo VD, Wakem GA & Youmbi E, 2018. Effect of mycorrhization and soluble phosphate on growth and phosphorus supply of Voandzou (*Vigna subterranea* (L.) Verdc.). Legume Research 41(6): 879–84.

Tetteh JP & Opoku-Asiama Y, 1988. Induced mutations for the improvement of bambara groundnut (*Voandzeia subterranea* (L.) Thou.), cowpea (*Vigna unguiculata* (L.) Walp.) and winged bean (*Psophocarpus tetragonolobus* (L.) DC.). In IAEA (ed.), Proceedings of a workshop on the improvement of grain legume production using induced mutations. Pullman, Washington: International Atomic Energy Agency.

Timu GA, Mulwa R, Okello J & Kamau M, 2014. The role of varietal attributes on adoption of improved seed varieties: The case of sorghum in Kenya. Agriculture and Food Security 3: 9.