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Farmers' perspective toward a demand led yam breeding in Nigeria

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This study seeks to increase the efficiency of yam breeding practice using farmers' insight at the trait and socioeconomic levels. A three-staged multisampling procedure was employed and 792 yam farmers from four geopolitical zones, comprising 10 states and the Federal Capital Territory, Abuja in Nigeria were randomly selected. Farmer's preference criteria and factors pertinent to improving the efficiency of yam breeding in Nigeria were documented. The data obtained were analyzed using a 5-point Likert scale to identify major traits farmers consider in the yam cultivar selection decision. Kendall's coefficient of concordance was used to measure the degree of agreement of ranking among the farmers. Factors influencing farmers' trait preference for yam cultivars were evaluated using a multinomial-ordered logistic regression model. The result revealed that yam varieties with high germination rates, disease-free quality, big tuber sizes, early maturity, and good pounding attributes are held in high esteem. The most critical constraint limiting the production of yam in the study area includes pest and disease attack, climate change, high cost of seed yam, high cost of staking, and weed infestation. Sex, age, access to credit, membership to yam association, total land owned, and years of experience as a yam farmer significantly influence farmers' ability to select yam cultivars with preferred attributes. A strategic effort needs to be given to these farmers' desired yam attributes and factored into developing improved yam varieties for increased adoption and enhanced food security in Nigeria.

KEYWORDS

yam, farmers, traits, constraints, breeding

1. Introduction

Yam (*Dioscorea* spp.) is the common name for a monocotyledonous tuber-producing vine plant with several species (approximately 600) (Mondo et al., 2020). It is widely cultivated as a staple food in Africa, Asia, South America, the West Indies, and the Pacific Islands (Obidiegwu and Akpabio, 2017). Among the cultivated species, the white yam (*Dioscorea rotundata*) is popularly grown in West Africa, while the water yam (*Dioscorea alata*) has a global production outlook (Darkwa et al., 2020). Yam serves as a major source of food and income for many people along the yam value chain (Scott et al., 2000; Maikasuma and Ala, 2013; Agre et al., 2023). Yam has cultural, social, economic, and religious value in most African societies (Obidiegwu and Akpabio, 2017), as well as in most therapeutic potentials (Obidiegwu et al., 2020). Millions of people depend on yam as a major source of calories and nutrition (Degras, 1993; Asiedu and Sartie, 2010). Nigeria ranks as the leading producer of white yams in the world, accounting for 66% (approximately 50.1 million tons) of annual global production (FAO, 2021).

Farming in Nigeria is characterized by smallholder farmers, who typically practice subsistence farming. The major producers of yam carry it out on parcellated plots using crude implements (Nahanga and Vera, 2014; Oseni et al., 2014). While population growth is significantly high, the amount of yam produced per hectare has remained stagnant or is declining (Nahanga and Vera, 2015). The rate of annual increase in yam production has been slowing compared to earlier dramatic increases associated with area expansion (Barlagne et al., 2017). The productivity of yam continues to fall as most farmers are getting about 10 tons/ha when compared to a potential yield of 50 tons/ha in some cultivars (Frossard et al., 2017; Neina, 2021). It is obvious that yam production under the current extensive agricultural practices of expanding into new lands that Nigeria has enjoyed sometimes is not sustainable. It has been predicted that this decrease could be catastrophic unless steps are taken soon to change the situation (Manyong and Nokoe, 2001). This past pattern needs to be reversed to satisfy a growing demand by yam value chain actors. The decline in productivity is partly associated with shortened fallow periods and deteriorating soil fertility, degeneration of popular varieties, increasing levels of field and storage pests and diseases (e.g., nematodes, mealybugs, scales, anthracnose, and viruses), high tuber losses in storage, high costs of labor, scarcity, and high costs of clean (pest-free) planting material. Demand for yam is also prone to demand–supply chain issues related to the limited number of its processed products and poor market linkages.

Considering the aforementioned constraints, the National Root Crops Research Institute Umudike and the International Institute of Tropical Agriculture Ibadan (both in Nigeria) have codeveloped 35 yam varieties for the Nigerian market. The Yam Improvement for Income and Food Security in West Africa (YIIFSWA) project was a major platform for addressing the seed system challenge. A major fallout of this effort was the development of a sustainable formal seed system in Nigeria while developing technologies for high-quality seed yam production. This effort established hubs of commercial and village seed entrepreneurs through the improvement of local capacity for the production of clean seed. A commercial seed yam system that sustainably ensures that smallholder farmers have access to high-quality seed was a major delivery. The scaling of these efforts is ongoing, and we envisage continuous growth. However, there has been a slow uptake of newly developed varieties. It has been acknowledged that the adoption of new food crop varieties in sub-Saharan Africa (SSA) has been relatively slow compared with other parts of the world (Thiele et al., 2021). This limited uptake of new varieties and low varietal turnover could be attributed to the insufficient priority that is given to economic and valuable traits by breeding programs (Goddard et al., 2015). The process of varietal development in crops and their subsequent dissemination and adoption is an intricate activity that begins with setting breeding objectives and emerging a selection strategy for priority traits. It will entail the identification of traits of preference by farmers and end users while incorporating them in product profiles. Otegbayo et al. (2021) set the foundation by identifying textural qualities and color as critical user-preferred quality traits for pounded yam acceptability by the stakeholders including processors, and consumers. We seek to complement the aforementioned study by addressing some other market perspectives that will further enhance the efficiency of the yam breeding system in Nigeria.

Resolving this consultative process requires open discussion and partnership between plant breeders, other researchers, including social scientists, farmers, and other users such as traders and consumers with a view to understand the needs and preferences of different users and their importance (Christinck et al., 2005; Agre et al., 2023). Moreover, in most farming households, there are differences in roles and assets that can lead to the development of specific traits. These preferences may have explicit gender-measurable attributes. Mapping trait information according to the role and position that an actor occupies in the value chain, including gender-specific information produces extensive and relevant information about the variety, their traits, and specific uses. Hence, information on end-user traits is not adequately considered in most varietal adoption studies. We seek to give thoughtful attention to the trait preferences of farmers as the first step in developing a demand-driven breeding program.

2. Materials and methods

2.1. Description of study area

Ten states (Anambra, Ebonyi, Cross River, Edo, Benue, Oyo, Osun, Ekiti, Nasarawa, and Niger) and Federal Capital Territory (FCT) Abuja representing four geopolitical zones (North Central [NC], South West [SW], South East [SE], and South South [SS]) of Nigeria where yams are extensively cultivated were selected for this survey. Two states each were selected from SE and SS while six states were selected from SW and NC. In addition, the FCT which falls within NC was equally considered. The 10 states and FCT surveyed are located in three vegetative belts, namely, the Humid Rainforest, Derived Savanah, and Southern Guinea Savannah agroecological zones. The geographical representation of the coordinates of the study locations is presented in Figure 1.

2.2. Sampling technique and data collection

A total of 792 respondents were chosen from 11 states, namely, Anambra, Ebonyi, Cross River, Edo, Benue, Oyo, Osun, Ekiti, Nasarawa, Niger, and FCT. The respondents for the study were selected through the use of a three-staged multisampling procedure. Two out of three senatorial zones were selected from each state. The selection of two local government areas from each senatorial zone was done purposively. Two rural farming communities were chosen from each of the selected local government authorities (LGAs) through purposive sampling. Nine yam farmers were randomly chosen from among the communities under study, thus resulting in a total of 792 ($11 \times 2 \times 2 \times 2 \times 9$) respondents. The study population was drawn from the group of farmers working under the African Yam Project focusing on major yam-producing states in Nigeria. The sample size was determined, following Yamane (1967), which is expressed in equation 1 as follows:

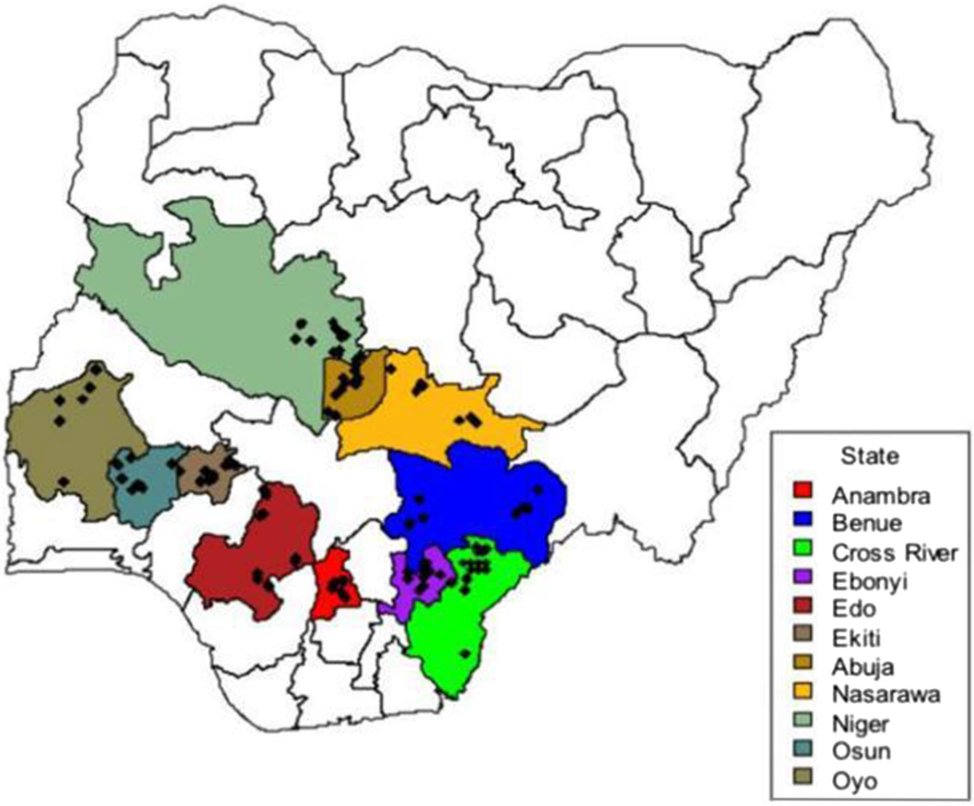

FIGURE 1
Map showing geographical areas of study location in Nigeria. ■ Study sites.

$$N = N / (1 + N(e)^2) \quad (1)$$

where n is the sample size, N is the population size, and e is the level of precision.

The data collected include demographic information, socioeconomic variables, institutional-and farm-level characteristics, consumer trait preference criteria, and production constraints experienced by the farmers in the study areas. Due to incomplete questionnaires and/or inconsistent data, a total of 745 fully completed questionnaires were used for analysis in this study.

2.3. Statistical analysis

A 5-point Likert model and Kendell's coefficient of concordance were used to identify preferred attributes and the degree of agreement in ranking among the farmers across the geopolitical zones. While production constraints were analyzed with the aid of descriptive statistics such as mean, frequency, and percentage, multinomial ordinal logistic regression was used to estimate the influence of sociodemographic parameters such as age, years of experience, farm size, marital status, family size, and education level on farmers' varietal selection decision. The study ascertained the major traits considered by farmers in yam variety selection decision. These traits were categorized into five levels for the purpose of ranking in the following order: "Very Important" (1), "Important" (2), "Moderately Important" (3), "Neutral" (4), and "Not Important" (5). The highest-ranked category was assigned a value of 1. All statistical analyses were done in an open-source R environment version 4.2.2 (R Core Team, 2022) while utilizing the packages, namely, "Tidyverse," "Readxl," "agricolae," "dplyr," "ordinal," "rgdal," "sp.," "rgeos," "raster," and "DescTools."

2.4. Theoretical framework

In an ordered response model, the analysis is usually performed based on less restrictive assumptions. The scores are assumed to be measured on an interval scale; in a real sense, the score represents an order of the responses (Maddala, 1983). The assumption is that the scores represent ordered segments of a utility distribution. In modeling the factors that influence farmers' decision to consider certain traits before selecting a yam variety, the study adopted a qualitative response regression model approach because the dependent variable (preferred traits of importance in yam variety selection decision) was measured qualitatively.

Furthermore, for dependent variables that are not ordered and are polytomous, the use of multinomial logit is most appropriate (Deressa et al., 2010; Etwire et al., 2013). However, it is unsuitable in cases when the dependent variable is ordered, because of its inability to account for the ordinal nature of the dependent variable (Greene, 2003). Under this situation, the use of ordered logit is more proper. Ordered logistic regressions have been employed in empirical studies such as the study by De Groote et al. (2010). This study used ordered logit because yam producers ranked the traits they considered in selecting yam variety and the order of rank was used as the dependent variable.

Participating farmers score a trait of a certain variety in a particular ordered category, driven by a latent, unobserved variable U as expressed in equation 2, which represents utility or indicates a preferred trait in a particular variety. As a substitute for this latent variable U, we observe the scores y, a variable that falls in one of m ordered categories, which in this study lie between "Very Important" (1) to "Not Important" (5). The scores are then connected to the latent variables through the limit points from N_1 to N_{m-1}, which are expressed as follows:

$$y = 1 \text{ if } U < N_1$$

$$y = 2 \text{ if } N_1 \le U < N_2 \qquad (2)$$

$$y = m \text{ if } N_{m-1} \le U$$

where y's are the ordinal numbers and U represents traits considered in a yam variety selection decision. This can be analyzed using standard quantitative methods, for example, the linear model (Train, 2003). This is explicitly expressed in equation 3 as follows:

$$U_i = \beta^i a_i + \varepsilon_i \qquad (3)$$

where U_i is the utility of individual i, a_i is a set of variables influencing the i's utility and choice, β is a vector of parameters to be estimated, and ε_i is the error term.

The probability of the scores y can now be derived from this model. The first outcome's probability, with a set of independent variables, a_i, is expressed in equation 4 as follows:

$$P(y=1) = P(U < n_i) = P\left(\varepsilon < N_i - \beta^i a\right) \qquad (4)$$

The distribution function for error term, ε, needs to be assumed to enable one to estimate these probabilities from the survey data. Here, the logistic distribution is often applied due to its convenient closed for cumulative distribution function (cdf) that is expressed in equation 5 as follows:

$$P(\mathrm{a} < \mathrm{a}) = \frac{1}{\left(1+e^{-a}\right)} = \frac{e^{a}}{\left(1+e^{a}\right)} \qquad (5)$$

The probability for the lowest score can now be derived from the cdf as follows:

$$P(y=1) = P\left(\varepsilon < n1 - \beta^i a\right) = \frac{e^{n1} - \beta^1 a}{1 + e^{n1} - \beta^1 a} \qquad (6)$$

The logs of the probabilities for the different outcomes can be multiplied to obtain the log likelihood of the variables of these outcomes. The coefficients, β, and the cutoff points, n^i, are the outputs of maximum likelihood estimation. This model is known as the ordered logit model (Train, 2003).

The effect of the independent variables of farmers' preferences is quantified by the value of the coefficients but the odds ratios of the cumulative probabilities allow easier interpretation of the result. In deriving the odds ratios, here the cumulative probability of a score m is defined as the probability of a score to be equal to or less than m, and this can be derived from the logistic cdf as follows:

$$P(y \le m) = \frac{e^{n1} - \beta^1 a}{e^{n1} - \beta^1 a} \qquad (7)$$

The odds ratio of an event (q) to occur is the probability it occurs over the probability it does not. This is mathematically expressed as $p(q)/[1-P(q)]$. For the ordered response model, the odds ratio for the lowest score to occur is $p(y=1)/1-P(y=1)$; conclusively, the cumulative odds ratio is the ratio that a score y falls at or below a certain level, j, or $P(y \le m)/1-P(y \le m)$. The cumulative odds ratio can be derived in equation 8 as follows:

$$\frac{P(y \le m)}{1-P(y \le m)} = \frac{e_m^n - \beta^1 a}{1+e^{n1} - \beta^1 a} \Big/ \left(1 - \frac{e_m^n - \beta^1 a}{1+e^{n1} - \beta^1 a}\right)$$
$$= \frac{e_m^n - \beta^1 a}{1+e^{n1} - \beta^1 a} \Big/ \left(\frac{1}{1+e^{n1} - \beta^1 a}\right) = e^{n1} - \beta^1 a \quad (8)$$

It follows that the logarithm of the cumulative odds ratio is a linear function of the independent variable:

$$\ln \frac{P(y \le j)}{1-P(y \le j)} = \ln\left(e^{n1} - \beta^1 a\right) = n_m - \beta^1 \qquad (9)$$

Now, we are interested in the effects of the variable a. For a change of a from a_1 to a_2, we will have a log odds ratio of

$$\left(\frac{P(y \le m|a=a_2)/1-P(y \le m)|a=a_2)}{P(y \le m|a=a_1)/1-P(y \le m)|a=a_1)}\right) = \beta^1(a_2 - a_1) \quad (10)$$

This odds ratio is independent of m. The model is, therefore, referred to as a "proportional odds" model (Mccullagh, 1980). The odds ratios in favor of a high score ($y > m$) vs. a low score (y'' m) are in the same proportion for two different values of a, irrespective of the value of m. The coefficient β can be interpreted as the change in the log odds ratio for a unit change in the explanatory variable, a; so, the log odds ratio of a trait having a low score rather than high to the odds ratio of the trait having a high score rather than low. This ratio is called the log odds ratio and its exponent, $e^{\beta 1}$, represents the odds ratio that an attribute is more considered over the same odds ratio for another attribute.

2.5. Analytical framework

According to Tetteh et al. (2011), the total rank score for each trait was calculated and the trait with the lowest score was interpreted as the most preferred. The coefficient of concordance is analytically expressed in equation 11:

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$$W = \frac{12\left[\sum X^2 - (\sum X)^2 / n\right]}{nm^2\left(n^2 - 1\right)} \quad (11)$$

where X is the sum of ranks for traits being ranked, m is the number of farmers, and n is the number of traits being ranked. The coefficient of concordance W was tested for significance using the *value of p*.

3. Results

3.1. Socioeconomic, institutional, and farm-level characteristics of the respondents

Table 1 presents the result of the socioeconomic, institutional, and farm-level characteristics of the respondents by agroecologies. The result shows that 76.9% (SE), 84.4% (SS), 91.3% (SW), and 84.7% (NC) of the respondents from the four regions under study were men. This implies that the cultivation of yam in these geopolitical regions was dominated by men. Yam farming and ownership is regularly associated with gender and class, which represents male accomplishment and social status (Martin et al., 2013). The cultivation techniques of yam have been diversely pronounced as exacting and labor-demanding (Obidiegwu and Akpabio, 2017) because activities such as clearing the forest and making big mounds for planting seed yam require energy. Ohadike (1981) and Chiwona-Karltun (2001) reported that the masculine labor required in yam production contributed to the expansion of cassava production (perceived to be more female-oriented) in the lower Niger State at the turn of the 20th century. This trend was obvious due to the scarcity of men occasioned by war at that time. The result further shows that yam farmers who participated in the study were between the ages of 20 and 83 years. The average age of farmers from SE and SS regions was 49.7 and 48.6 years, respectively, while that of SW and NC were 47.6 and 44.1 years, respectively. This observed age indicates that yam farmers from the study locations were among the young population who have youthful potential for yam productivity in Nigeria. The mean farming experience of the respondents was 24.3 and 24.7 in SE and SS, respectively, while 23.7 and 25.1 were recorded in SS and NC, respectively. More than 70% of the farmers from the four zones under study had access to primary and secondary education. Farmers in the SE region have more years of formal education (43.9%) when compared with those in the NC region (30.3%). Institutional variable results show that most farmers are not members of the yam farmers' association. The percentage of farmers who belong to one association or the other varies across the different regions with SS having the highest value (74.9%). Farmers' ability to access credit in SS was highest with more than 60% of the farmers from SS having access to credit. Most yam farmers were not visited by extension agents during the period of study. Only 11.9 and 17.6% of farmers from NC and SS, respectively, were visited by extension agents. The farm-level information shows that yams were cultivated in a farm size ranging between 0.01 and 30 ha with a mean of 2.68 ha. Yam production was the major source of income for the farmers surveyed as 53% earn more than half of their livelihood from the sale of yam.

3.2. Farmers' preferred traits across gender and cultural patterns in the study area

Table 2 presents the result of the ranked order of traits considered by farmers from SS and SE geopolitical zones of Nigeria in yam variety selection decision. It was observed from the result that yam with a "high germination" rate was the most considered trait in yam variety selection decision across the two geopolitical zones and among male and female yam producers. However, the ranking order of these traits varied from one geopolitical zone to another. High germination, tuber size, and tuber free from rot were among the first three traits that are highly considered by male farmers in SE Nigeria. Female yam farmers in the same region prefer yam varieties that are disease-free with big tuber sizes and high germination rates. Culinary quality such as pounded yam quality was an important trait that male farmers in SS Nigeria consider in yam selection decisions while yam varieties that are free from disease merited the attention of female yam farmers from SS Nigeria. Kendell's coefficient of concordance shows that 30 and 70%, respectively, of male and female farmers from SE, with 55 and 63% of male and female farmers from SS of the sampled population agree with each other on the order of ranking these traits.

Table 3 presents the result of the ranked order of traits considered by farmers from SW and NC geopolitical zones of Nigeria in yam variety selection decision. The result depicts that SW male yam farmers value yam variety that matures early and has high germination with big tuber sizes while female yam farmers consider yam variety that has a high germination rate with good tuber shape with high market value. The result from Table 3 shows that both male and female yam farmers from the NC zone consider tuber size as a major selection criterion. In addition, yam varieties with good pounding attributes were equally considered important as they ranked second and third for male and female yam farmers, respectively. Late maturing variety was the least trait to be considered in yam variety selection decision as it ranked last in all the zones. This trend was observed in both genders. The level of agreement among male and female yam farmers from the two regions was above 50% and highly significant.

3.3. Yam production constraints and accessibility of preferred yam varieties across the study zones

The challenges associated with the declining yam production by surveyed farmers in Nigeria are presented in Table 4. The result as shown in Table 4 confirms that among the 13 identified constraints hindering production, the problem of pest and disease attack (56.3%), climate variability/change (27.5%), high cost of seed yam (13.8%), and high labor cost were the most mentioned by SE yam farmers. In SS, most yam farmers face the problem of pest and disease attacks (50%), high cost of farm inputs (18.8%), and low soil fertility (17.5%). The major challenge for yam farmers in the SW region was a change in climate (61.3%), low soil fertility (33.8%), and low yield (17.5%). The NC yam farmer was constrained by the high cost of farm inputs (72.5%), pest/disease attacks (47.5%), and poor soil fertility (45%). The high cost of farm inputs and declining soil fertility also serve as a hindrance to yam cultivation in NC with recorded values of 72.5 and 45%, respectively. The issue of climate change (61.5%) was experienced more by farmers in the SW zone followed by pest and disease attacks

TABLE 1 Distribution of respondents' socioeconomic, institutional, and farm-level characteristics according to geopolitical zones of Nigeria.

Variables	SE		SS		SW		NC	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Gender								
Male	123	76.86	135	84.38	157	91.28	232	84.67
Female	37	23.13	25	15.63	15	8.72	42	15.33
Total	160		160		172		274	
Age (years)								
21–30	8	5	6	3.75	5	2.905	36	14.184
31–40	42	26.25	38	23.75	52	30.21	77	30.338
41–50	38	23.75	54	33.75	52	30.21	73	28.762
51–60	35	21.875	35	21.875	39	22.659	39	15.366
61–70	30	18.75	23	14.375	24	13.944	27	10.638
71–80	7	4.375	4	2.5			2	0.788
Total	160		160		172		254	
Level of education								
0–6	69	43.125	50	31.25	68	39.78	77	30.338
7–12	63	39.375	67	41.875	65	38.025	68	26.792
13-16	28	17.5	43	26.875	38	22.23	109	42.946
Total	160		160		171		254	
Farming experience								
1–9	29	18.125	19	11.94	42	24.71	60	23.62
10–19	47	29.375	55	34.59	68	40	75	29.53
20–29	38	23.75	50	31.45	32	18.82	67	26.38
30–39	26	16.25	25	15.725	17	10	28	11.02
40–49	15	9.375	8	5.032	9	5.29	17	6.69
50–59	3	1.875	1	0.629	1	0.588	5	1.97
60–69	2	1.25	2	1.258	1	0.588	2	0.79
Total	160		159		170		254	
Household head								
Yes	136	85	134	84.286	160	93.57	221	87.00
No	24	15	25	15.725	11	6.43	33	12.99
Total	160		159		171		254	
Visit of extension agents								
Yes	40	25	28	17.61	72	41.86	30	11.86
No	120	75	131	82.39	100	58.14	223	88.14
Total	160		159		172		253	
Access to credit								
Yes	41	25.63	52	32.71	116	67.44	34	13.39
No	119	74.38	107	67.30	56	32.56	220	86.61
Total	160		159		172		254	
Member to yam cooperative								
Yes	28	18.42	19	11.95	128	74.85	92	36.22
No	124	81.58	140	88.06	43	25.14	162	63.77
Total	152		159		171		254	

(Continued)

TABLE 1 (Continued)

Variables	SE		SS		SW		NC	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Total land area owed								
0.1–5.0	120	75.00	81	50.625	48	27.91	139	50.73
5.1–10	30	18.75	42	26.25	34	19.77	72	26.28
10.1–20	6	3.75	28	17.5	39	22.67	32	11.68
20.1–30	3	1.875	6	3.75	22	12.79	12	4.38
30.1–40	0	0	1	0.625	5	2.91	6	2.19
40.1–50	1	0.625	2	1.25	7	4.07	9	3.28
50.1–60	0	0	0		17	9.88	4	1.46
Total	160		160		172		274	
Land area planted with yam								
0.01–1	81	50.625	65	40.885	37	21.76	116	45.84
1.01–2	33	20.625	37	23.27	52	30.58	51	20.16
2.01–3	22	13.75	18	11.32	33	19.40	33	13.04
3.01–4	9	5.625	12	7.55	11	6.47	12	4.74
4.01–5	6	3.75	13	8.18	12	7.06	10	3.95
>5.01	9	5.625	14	8.81	25	14.7	31	12.25
Total	160		159		170		253	

Computed from field survey 2021. SE, South East; SS, South South; SW, South West; and NC, North Central.

(33.8%). Farmers' major constraints in NC were the high cost of farm input (72.5%) and the prevalence of pests and diseases (47.5%).

The barriers limiting the accessibility of the preferred yam varieties are presented in Table 5. The result shows that the high cost of the preferred yam varieties makes it inaccessible for farmers from the four regions under study in the following order: SE (30.2%), SS (61.0%), SW (63.5%), and NC (83.3%). Non-availability is seen as a barrier limiting the accessibility of preferred yam varieties, and this is observed in the following order: SS (11.3%), NC (17.2%), SE (18.6%), and SW (19.2%).

3.4. Socioeconomic factors influencing yam farmers' varietal selection decision across the study area

Table 6 shows the result of multinomial ordinal logistic regression of factors influencing yam farmers' decision in variety selection. The odds ratios of factors influencing yam farmer selection decision indicate that variables such as age, farm experience, access to credit, visit of extension agent, membership to yam association, and percentage income from the sale of yam influenced SE yam farmers' decision to select yam varieties that are big in tuber size, high in germination, and pest-free. The estimated coefficient of age and farming experience was found to have a positive and significant influence on yam farmers' selection decision criteria. This implies that the yam farmer unit change in age and farming experience will influence the decision to select a variety with big tuber size by 0.99 unit. The result further shows that the yam farmer's ability to select a variety with high germination rate was influenced by age and percentage income from the sale of yam. This result further indicates that a change in log odds ratio of 0.92 unit (age) and 0.99 unit (percentage income from yam) will influence a farmer's ability to select a variety with high germination rate. Our result shows that in SS Nigeria, yam farmers' decision to select a yam variety with high germination was determined by the total area cultivated with yam while selecting a yam variety with good tuber appearance was influenced by gender and percentage income from yam. The area under yam cultivation was found to have a significant influence on farmers' selection decisions. The log odds ratio in favor of selecting a variety with high germination rate increases by 0.98 units if a farmer accesses an additional hectare of land for yam cultivation.

Table 7 shows the result of the coefficient of odds ratios of factors that influences yam farmer selection decisions in SW and NC geopolitical zones of Nigeria. In the SW zone of Nigeria, the estimated coefficients of extension visits and access to loans influenced the decision to select the yam variety with good pounding attributes and early maturity. The ability of yam farmers in NC to select yam variety with big tuber size, good pounded attributes, and high germination rate could be determined by age, farming experience, membership of cooperatives, and total cultivated area.

4. Discussion

4.1. Farmers' preferred traits across gender and cultural patterns in Nigeria

To facilitate farmers' level of adoption of new yam varieties, understanding the criteria for varietal selection plays an important role and helps in guiding breeders and crop improvement experts (Fiacre et al., 2018). Farmers' trait preferences were similar across gender and geopolitical zones. Both male and female yam farmers considered variety with high germination rate, free from diseases, and having big tuber size in their selection decision. However, in SS and

TABLE 2 Distribution of respondents according to trait preference considered in yam variety selection decision by gender in South East and South South geopolitical zones of Nigeria.

Preferred trait	SE				SS			
	Male	Rank	Female	Rank	Male	Rank	Female	Rank
High germination or sprout emergence	1.24	1	1.38	3	1.29	2	1.44	2
High field establishment rate	1.49	14	1.62	15	1.43	13	1.48	6
Plant vigor (attractive growth)	1.39	5	1.49	10	1.30	3	1.52	8
Drought resistance	1.61	17	1.65	16	1.47	15	2.12	29
Tolerance to low soil fertility (grows well in all soil types)	1.41	7	1.38	4	1.37	9	1.64	16
Disease-free (clean leaves and vines with no visible disease)	1.42	10	1.27	1	1.37	10	1.4	1
High vegetation	1.72	22	1.92	26	1.72	25	1.76	22
Early maturity	1.36	4	1.65	17	1.39	11	1.44	3
Less likely to depend on staking (grow well under no staking)	2.09	27	2.19	27	2.23	28	2.32	30
Late maturity	4.01	31	4.30	31	3.13	31	3.4	31
Tuber yield	1.58	16	1.57	13	1.50	17	1.48	7
Tuber size	1.25	2	1.32	2	1.34	5	1.76	23
Tuber appearance (smoothness of skin)	1.48	13	1.54	11	1.41	12	1.56	10
Tuber shape	1.72	23	1.59	14	1.60	24	1.84	26
Tubers less susceptibility to deformation in soil (free from deformation)	1.93	25	1.86	24	1.51	20	1.64	17
Tubers free from diseases (rots)	1.51	15	1.41	6	1.34	4	1.44	4
Tubers free from pests (nematodes and scale insects)	1.26	3	1.44	9	1.35	7	1.52	9
Tuber flesh oxidation (non-browning or discoloration)	2.66	29	2.68	29	2.66	29	1.84	27
Tuber flesh color	1.65	18	1.54	12	1.60	23	1.6	13
Tuber firmness (higher dry matter an not too watery)	1.95	26	1.70	19	1.50	16	1.64	18
Cooking quality (fast cooking)	1.69	20	1.65	18	1.43	14	1.8	25
Pounded yam quality (taste, aroma, moldability, firmness, color, and stretchability)	1.39	6	1.41	7	1.28	1	1.56	11
Boiled yam quality (aroma, taste, firmness, mealiness, and color)	11.41	8	1.38	5	1.34	6	1.68	19
Fried yam quality (aroma, taste, and firmness/mealiness)	1.75	24	1.78	22	1.73	26	1.88	28
Peel loss	2.83	30	3.11	30	2.99	30	1.76	24
Tuber storability: long shelf-life or storage life without spoilage	1.42	11	1.76	21	1.35	8	1.44	5
Tuber dormancy (can stay long or short after harvest without sprouting)	2.31	28	2.35	28	1.81	27	1.6	14
Seed yam Hygiene (tubers clean or not)	1.67	19	1.81	23	1.51	18	1.72	20

(Continued)

TABLE 2 (Continued)

Preferred trait	SE				SS			
	Male	Rank	Female	Rank	Male	Rank	Female	Rank
Certified seed yam (seed yam certified or not)	1.71	21	1.89	25	1.59	22	1.72	21
Price of seed yam	1.45	12	1.70	20	1.56	21	1.6	15
Price of ware yam (marketability)	1.41	9	1.41	8	1.51	19	1.56	12
Kendall coefficient of concordance	0.3		0.749		0.551		0.633	
Value of *p*	0.0000		0.0000		0.0000		0.0000	

Computed from field survey 2021. SE, South East; SS, South South.

NC, the culinary quality trait, such as pounded yam attributes, was considered by male farmers from this region. It is exciting to observe that the *Tiv* and *Idoma* areas of the NC are among the major consumers of pounded yam which has a high cultural value in Nigeria (Nweke et al., 2013). The drivers of good pounded yam attributes including texture, mealiness, stretchability, and non-adhesiveness should be accorded high priority in selection and crop improvement strategies.

The female farmers from SS and NC selected a yam variety that matures early over late maturing ones. The majority of the respondents disclosed *via* personal communication that they would want the yam that could be harvested within 6 months because it will provide early food and cushion the food scarcity that is predominant within the cropping season pending harvest. A female respondent from Ikom, Cross River State highlighted that "beyond food provision for the family, yam farming provides an avenue to raise fund to address various family challenges." Musimbi (2007) had earlier identified early maturity as a trait usually considered by women when making varietal selection decisions. It, thus, suffices that yam product development will prioritize these gender dimensions within the product development stage. It is interesting to note that female farmers in NC and SE prefer yams with big tuber sizes because of their market appeal and ceremonial/cultural rites that go with big tuber sizes in the region. The big tuber size reduces the burden placed on these women to purchase sizeable products, especially during marriage ties of a close family member or children (Obidiegwu and Akpabio, 2017).

One of the gender-sensitive findings is the preference for tuber shape recorded among the female farmers from SW partly because women are actively involved in yam marketing and processing (Omojola, 2021). Thus, it becomes logical and demand-driven to develop gender-sensitive products that incorporate tuber size, high germination, disease-free, good shape, and early maturing with good pounded yam quality across diverse yam agroecologies in Nigeria.

4.2. Yam production constraints and accessibility of preferred varieties across the study zones

From this study, biotic and abiotic factors like pest/diseases attack, climate variability/change, and poor soil fertility were among the major challenges affecting the production of yam in the study areas. The attack of pests and diseases has been identified as a major constraint to yam production. Parasitic nematodes, fungi, and virus attacks, as well as leaf and tuber insects such as beetles, reduce tuber yield by 40% (Zaknayiba and Tanko, 2013). The variability in climate parameters significantly produces a changing pattern of rainfall and increased temperature across the different agroecological zones of Nigeria (Mondo et al., 2020). Agricultural practice in Nigeria is rainfed so rainfall anomalies will pose a great challenge to farmers. There has been a record of flooding in yam-producing regions such as the NC which resulted in the loss of farmland and farmers being displaced from their communities. Nigerian farmers have also experienced a series of drought events, which has caused physiological stress to field crops (Shiru et al., 2020). Diminishing soil fertility is what characterizes Nigerian soil due to intense farming activities. These barriers limit yam yield because most soil under yam cultivation in the NC and SE regions of Nigeria is observed to have reduced nitrogen, soil organic matter, and cation (Neina, 2021). The aforementioned challenges are well documented, but our study observed an increasing trend of drought spells, high rainfall patterns, declining soil fertility, and high cost of farm inputs occasioned by increasing inflationary trends in Nigeria.

This benchmark information drives the need to address biotic and abiotic stresses in the context of product profiling within the breeding programs. The direct and indirect drivers of traits should form the core of a scientific inquiry that will be built into the breeding pipeline so as to guide the development of products that can address the aforementioned biotic and abiotic challenges. It was affirmed by Nahanga and Vera (2015) that insufficient farm input serves as a constraint to yam production in developing countries like Nigeria, Ghana, Ivory Coast, Benin, and Togo. According to Bassey (2017), the cost of planting materials represents approximately 50% of the cost of yam production. It was further observed from the result that the non-availability of the preferred seed yams hinders them from reaching the farmers. The high cost of labor, weed infestation, staking, and high cost of seed yam also act as a barrier to yam production in the study area. The private seed sector, mainly driven by commercial and local seed entrepreneurs, has a strategic role in ensuring that certified seeds get to the farmers. This can be promoted by encouraging key investors in the formal seed system. Efforts need to be prioritized toward the development and standardization of technologies for high ratio propagation of high-quality breeder and foundation seed yams. The gaps in knowledge concerning pests (nematodes) and diseases (viruses and fungi) should be accorded prompt attention while developing sensitive and cost-effective management and diagnostics for major yam biotic challenges. Selecting non-stake bushy-type yams will significantly reduce the labor cost required for cutting, transporting, and placing stakes as well as reducing the burden of trailing yam vines onto stakes.

TABLE 3 Distribution of respondents according to trait preference considered in yam variety selection decision by gender in South West and North Central geopolitical zones of Nigeria.

Preferred trait	SW				NC			
	Male	Rank	Female	Rank	Male	Rank	Female	Rank
High germination or sprout emergence	1.14	2	1.13	1	1.13	3	1.18	5
High field establishment rate	1.22	5	1.27	7	1.25	12	1.18	6
Plant vigor (attractive growth)	1.43	13	1.47	14	1.27	13	1.45	13
Drought resistance	1.57	18	1.53	16	1.41	19	1.64	18
Tolerance to low soil fertility (grows well in all soil types)	1.87	23	2.27	29	1.73	26	1.68	20
Disease-free (clean leaves and vines with no visible disease)	1.87	24	2.00	24	1.78	28	1.55	16
High vegetation	1.35	10	1.20	4	1.40	18	1.68	21
Early maturity	1.11	1	1.20	5	1.20	5	1.14	2
Less likely to depend on staking (grow well under no staking)	1.46	14	1.47	15	1.90	29	2.45	29
Late maturity	2.71	31	2.47	31	3.62	31	3.45	31
Tuber yield	1.88	25	2.00	25	1.23	9	2.05	27
Tuber size	1.14	3	1.40	11	1.09	1	1.09	1
Tuber appearance (smoothness of the skin)	1.37	11	1.27	8	1.21	8	1.23	7
Tuber shape	1.35	9	1.13	2	1.34	14	1.50	14
Tubers with less susceptibility to deformation in soil (free from deformation)	1.88	26	1.93	22	1.50	21	1.62	17
Tubers free from diseases (rots)	1.54	17	1.93	23	1.20	7	1.36	11
Tubers free from pests (nematodes and scale insects)	1.60	19	1.73	20	1.23	10	1.32	9
Tuber flesh oxidation (non-browning or discoloration)	1.65	20	1.33	9	1.61	22	2.09	28
Tuber flesh color	1.47	15	1.33	10	1.62	23	1.82	25
Tuber firmness (higher dry matter and not too watery)	1.88	27	2.00	26	1.68	25	1.77	24
Cooking quality (fast cooking)	1.31	8	1.40	12	1.36	17	1.50	15
Pounded yam quality (taste, aroma, moldability, firmness, color, and stretchability)	1.14	4	1.20	6	1.10	2	1.14	3
Boiled yam quality (aroma, taste, firmness, mealiness, and color)	1.39	12	1.53	17	1.25	11	1.32	10
Fried yam quality (aroma, taste, and firmness/mealiness)	1.72	21	1.60	18	1.49	20	1.68	22
Peel loss	2.08	28	2.00	27	2.04	30	2.50	30
Tuber storability: long shelf-life or storage life without spoilage	1.22	6	1.40	13	1.15	4	1.14	4
Tuber dormancy (can stay long or short after harvest without sprouting)	2.28	30	2.40	30	1.62	24	1.82	26
Seed yam Hygiene (tubers clean or not)	1.51	16	1.73	21	1.35	16	1.68	23
Certified seed yam (seed yam certified or not)	2.11	29	2.20	28	1.76	27	1.64	19
Price of seed yam	1.83	22	1.67	19	1.34	15	1.36	12
Price of ware yam (marketability)	1.28	7	1.13	3	1.20	6	1.27	8

(Continued)

TABLE 3 (Continued)

Preferred trait	SW				NC			
	Male	Rank	Female	Rank	Male	Rank	Female	Rank
Kendall coefficient of concordance	0.643		0.569		0.715		0.692	
Value of p	0.0000		0.0000		0.0000		0.0000	

Computed from field survey 2021. SW, South West; NC, North Central.

TABLE 4 Constraints affecting yam farmers across agroecology in Nigeria.

Constraints	NC (%)	SE (%)	SS (%)	SW (%)
Climate change	16.25	27.5	11.25	61.25
Cost of seed yam	8.75	13.75	1.25	2.5
High cost of farm inputs	72.5	11.25	18.75	10
High cost of labor	22.5	25	18.75	16.25
Insecurity	17.5	1.25	0	5
Lack of improved seeds	5	7.5	7.5	1.25
Low sprouting	8.75	0	5	17.5
Low yielding	10	10	2.5	5
Pest/disease attacks	47.5	56.25	50	33.75
Poor soil fertility	45	10	17.5	3.75
Staking	2.5	5	11.25	0

SE, South East; SS, South South; SW, South West; NC, North Central.

TABLE 5 Constraints in accessing preferred yam varieties.

Factors	NC (%)	SE (%)	SS (%)	SW (%)
High cost	83.3	63.5	61.0	30.2
Lack of information	0.6	1.9	1.9	2.3
Market distance	4.0	0.6	4.4	2.9
Never seen improved seed	0.6	0.0	9.4	0.0
No constraint	6.3	2.6	2.5	2.3
Non-availability	17.2	18.6	11.3	19.2

SE, South East; SS, South South; SW, South West; NC, North Central.

5. Conclusion

This study provides information on farmers' preferred traits as well as constraints limiting yam production. The wealth of information generated forms a good foundation for cross-cutting considerations and policy interventions in yam crop improvement system. The identified factors responsible for influencing farmers' decision to select yam varieties with preferred traits are age, farm experience, access to credit, visit of extension agents, membership to yam association, percentage income from the sale of yam, extension visit, and access to loan. The SE and SS yam farmers prefer yam varieties with big tuber size, high germination rate, no pest issue, and good tuber appearance. While farmers in SW and NC desire good pounding quality and early maturity, other important traits to be considered within the breeding programs include tuber storability, high field establishment, and tolerance to low soil fertility. The adoption of yam varieties can be improved through access to loans, regular visits by extension agents, and regular training of yam farmers. Strengthening the capacity of key service providers in national extension, advisory services, and non-governmental organizations (NGOs) through training will ensure that not only significant numbers of beneficiaries are reached but also that it will provide the opportunity for future sustainability and scalability. Regular participatory research activities and market intelligence updates with value chain actors will further strengthen the adoption of breeding innovations while providing the basis for achieving wide-scale impact.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the

TABLE 6 Odds ratio of factors influencing yam farmers' variety selection decision in South East and South South Nigeria.

Variable	SE			SS		
Odds ratios	Tuber Size	High Germination	Pest-Free	High Germination	Tuber Size	Tuber Appearance
Sex	1.14	1.42	1.92	2.77	2.86	1.66**
Age	0.99*	0.92*	0.96	0.95	0.96	0.98
Level of education	1.03	0.96	0.98	1.06	1.01	0.99
Farming experience	0.99**	1.04	0.99	1.07	1.03	0.98
Visit of extension agents	2.11	0.35	0.24	0.41	0.57	0.46
Access to credit	0.30*	2.58	0.83**	0.81	6.45	2.71
Accessed loan	0.37	0.49	1.25	2.32	0.73*	1.61
Member of yam association	0.14	1.41	0.51*	0.75*	1.26	2.14
Received training	0.18	1.00	0.75	2.58	0.21*	0.22
Total land owned	0.98	1.01	0.77	1.02	0.95	0.99
Total cultivated	1.03	0.96	1.21	0.98***	0.90	0.95
Years of yam farming experience	1.05	1.04	1.05	1.00*	1.02	1.04
Percentage of income from sale of yam	0.98	0.99*	1.08	0.99	1.00	0.99*
Log likelihood	−82.72	−80.70	80.52	−96.13	−114.16	−117.20
Value of *p*	2.8e-03	2.44e-12	6.84e-07	2.6e-13	1.1e-09	4.05e-13
N	142	142	142	159	159	159

*10 percent level of significance, **5 percent, and ***1 percent. SE, South East; SS, South South; N, Sample size.

TABLE 7 Odds ratio of determinants of factors influencing yam farmers' variety selection decision in SW and NC Nigeria.

Variable	SW			NC		
Odds ratios	Pounded yam quality	Early maturity	High Germination	Tuber size	Pounded yam quality	High Germination
Sex	1.92	2.28	0.74	0.54	1.63	1.60
Age	0.95	1.05	1.06	1.04	1.00*	1.05
Level of education	1.07	1.04	0.93	0.97	1.03	1.00
Farming experience	1.08	1.00	0.96	0.96*	1.00	0.99**
Visit of extension agents	0.59*	2.40	1.46	3.87	1.18	0.68
Access to credit	3.00	2.47	0.41	1.97	2.20	6.38
Accessed loan	0.99	0.51**	1.54	1.39	3.01	0.52
Member of yam association	0.19	1.59	0.72	0.27***	0.55	0.59
Received training	1.71	0.45	0.47	0.96	0.87	0.36
Total land owned	0.96	0.90	1.00	0.95	1.02	1.01
Total cultivated	1.02	0.98	0.96	0.81	0.84**	0.86
Years of yam farming experience	1.00	1.00	1.00	1.00	1.01	0.95
Percentage of income from sale of yam	1.00	0.98	0.97	0.98	0.98	1.00
Log likelihood	−52.81	−44.85	−58.48	−67.45	75.81	−78.01
Value of *p*	4.6e-09	4.7e-11	2.8e-08	3.8e-08	2.7e-05	7.3e-13
N	163	163	163	250	250	250

SW, South West; NC, North Central; N, Sample size.

participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

AA and JO conceptualized the study idea. CK, IN, AE, PAA, and JO took part in the survey study. AA, JO, PAA, and PA coordinated the data generation. CK, IN, and JO analyzed the data and wrote the first draft with inputs from AA, PA, and PAA. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1227920/full#supplementary-material

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