

Landraces persist where seed does not reach: genotype inventory, farmers' perception and demand for improved versus landrace yam (*Dioscorea* spp.) genotypes in Oyo State, Nigeria

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Abstract

Nigeria produces the majority of the world's yam, yet national tuber yields remain far below the crop's biological potential, and on-farm uptake of the improved varieties released since 2003 has stayed low. We characterised the yam genotypes actually cultivated across five yam-growing centres of Oyo State, south-western Nigeria, and related that inventory to farmers' reasons for their choice of planting material. Twenty-eight farmers in nine cooperative-based groups were interviewed with a structured instrument supported by focus group discussions, and on-farm accessions were assigned to species using a standard yam descriptor list. Thirty-five genotypes were recorded: 24 *Dioscorea rotundata* Poir., 9 *D. alata* L. and 2 *D. cayenensis* Lam. The descriptors separated the three species cleanly but resolved almost no variation within *D. rotundata*, where 24 accessions with distinct farmer names shared an identical state across eleven of twelve characters. Genotype richness ranged from 5 to 15 per farmer group and was highest at Ibadan; the first two principal components of the location × genotype matrix accounted for 70.9% of the variation. No farmer grew improved genotypes alone: 85.7% cultivated landraces exclusively. Only one improved genotype, VA Yam, was encountered, at low abundance, despite recording the highest mean tuber weight of any genotype weighed (3.9 kg). Farmers identified unavailability of seed yam, rather than unwillingness, as the operative barrier, while an introduced landrace of foreign origin had spread widely through farmer-to-farmer exchange alone. In this system the binding constraint on adoption is seed access rather than farmer conservatism.

Introduction

Yam (*Dioscorea* spp.) is a multi-species monocotyledonous crop grown across the humid and sub-humid tropics of Africa, Asia, Oceania and South America (Andres et al. 2017). The genus comprises roughly 644 species, of which about eleven are cultivated as food staples (Darkwa et al. 2020; Obidiegwu et al. 2020). Three species dominate world production, *Dioscorea rotundata* Poir., *D. cayenensis* Lam. and *D. alata* L., with the Guinea yam complex (*D. rotundata* and *D. cayenensis*) accounting for the bulk of West African output. Almost 94% of world production comes from West Africa, and 75–78% of that from Nigeria alone (FAO 2024; Stuart et al. 2021).

Beyond its caloric contribution, yam occupies a social position that few other African staples share. It is a ceremonial and festival crop, a store of household wealth, and a marker of status and identity in many communities of West and Central Africa (Obidiegwu and Akpabio 2017). Production, processing and trade provide substantial income to resource-poor households, and women derive a significant share of their earnings from the marketing end of the value chain, dominating yam sales even where men dominate production (Stuart et al. 2021). These non-agronomic dimensions matter for varietal choice: a yam variety is not evaluated by yield alone but by how it performs in the pounding mortar, how it stores through the dry season, and whether it commands a price in the local or export market.

Against this importance stands a persistent productivity gap. Current national tuber yield estimates fall below 10 t ha⁻¹ against an estimated biological potential of about 50 t ha⁻¹ (Fasusi et al. 2022; FAO

2024). The gap is driven by an interacting set of biotic and abiotic constraints: yam mosaic and yam mild mosaic viruses, anthracnose, nematodes and tuber beetles; declining soil fertility on continuously cropped land; high labour costs for mounding and staking; and, above all, the quantity and health status of planting material. Because yam is propagated vegetatively from tubers or setts, seed of poor sanitary status is recycled over many generations, and the resulting degeneration can cost a farmer up to half the harvest (Aighewi et al. 2015; Stuart et al. 2021). Planting material alone accounts for 25–30% of the investment in ware yam production (Mignouna et al. 2013).

Conventional yam improvement has made real progress against this constraint despite formidable biological obstacles: a long breeding cycle, erratic and often absent flowering, dioecy, polyploidy and a heterogeneous genetic background (Darkwa et al. 2020). Over the past two decades some twenty-four improved yam varieties have been released in Nigeria (AfricaYam 2018). Of these, twenty-two released since 2003 are registered in the national catalogue through the National Root Crops Research Institute (NRCRI), Umudike, in collaboration with the International Institute of Tropical Agriculture (IITA), with reported on-station yields of 22–44 t ha⁻¹ (Table 1; IITA 2024; Nigerian Seed Portal Initiative 2024). Successive seed system initiatives – the Yam Improvement for Income and Food Security in West Africa project (YIIFSWA and YIIFSWA-II), AfricaYam, CAY-Seed and, more recently, the SEED-EQUAL and PROSSIVA initiatives of One CGIAR – have targeted the parallel problem of getting clean planting material of those varieties into farmers' hands, using aeroponics, temporary immersion bioreactors and adapted miniset techniques to break the low multiplication ratio that has historically made seed yam scarce and expensive (Aighewi et al. 2015; Stuart et al. 2021).

Yet uptake of released varieties has remained low, and the informal, farmer-based seed system continues to supply the great majority of planting material in Nigeria (Stuart et al. 2021; Fig. 1). The pattern is not unique to yam: adoption of improved varieties across vegetatively propagated root, tuber and banana crops has repeatedly stalled well short of expectations, and seed system gaps rather than breeding output are increasingly identified as the reason (Almekinders et al. 2019; McEwan et al. 2021). The literature offers several explanations: limited awareness, farmers' preference for the culinary and storage qualities of landraces, the high initial cost of seed yam, and the mismatch between breeders' selection criteria and the traits end-users actually value (Kalu et al. 2023; Thiele et al. 2021). These explanations are not mutually exclusive, but they carry very different policy implications. If low adoption reflects awareness, the remedy is extension. If it reflects trait mismatch, the remedy is demand-led breeding. If it reflects the physical unavailability of seed, neither extension nor redirected breeding will move the needle until multiplication and distribution are solved. Distinguishing between these requires field evidence on what farmers actually grow, what is actually available to them, and what they say when asked.

Oyo State provides a useful setting for that question. It spans the derived savannah and Guinea savannah transition in south-western Nigeria, contains long-established yam production centres in its northern local government areas, and has been a target area for yam seed system interventions. Despite this, no systematic inventory of the genotypes under cultivation in the state, linked to farmers' stated

reasons for growing them, has been published. This study was undertaken to fill that gap. Its specific objectives were to: (i) inventory the yam genotypes cultivated across five yam-growing centres of Oyo State and confirm their species identity using standard descriptors; (ii) quantify genotype richness and compositional structure across locations; (iii) document farmers' perceptions of, and stated demand for, improved versus landrace genotypes; and (iv) identify which of the competing explanations for low adoption is best supported in this system, and what that implies for yam breeding and seed system design.

Table 1
Improved yam varieties formally released and registered in Nigeria, 2003–2024, with reported yield performance

Release name	Breeder code	Species	Year	Reported yield (t ha ⁻¹)
TDr 95/01924	TDr 95/01924	<i>D. rotundata</i>	2003	Stable yield; 32.8% dry matter
TDa 98/01166	TDa 98/01166	<i>D. alata</i>	2008	26–30
TDa 98/01168	TDa 98/01168	<i>D. alata</i>	2008	24–28
TDa 98/01176	TDa 98/01176	<i>D. alata</i>	2008	26–30
DRN 200/4/2	DRN 200/4/2	<i>D. rotundata</i>	2008	35
TDr 89/02602	TDr 89/02602	<i>D. rotundata</i>	2009	31.5
TDr 89/02660	TDr 89/02660	<i>D. rotundata</i>	2009	31
TDr 95/19158	TDr 95/19158	<i>D. rotundata</i>	2009	29.4
TDa 00/00104	TDa 00/00104	<i>D. alata</i>	2009	30
TDa 00/00194	TDa 00/00194	<i>D. alata</i>	2009	37.5
UMUDr-17	TDr 95/19177	<i>D. rotundata</i>	2010	30
UMUDr-18	TDr 89/02475	<i>D. rotundata</i>	2010	31
UMUDa-4	TDa 00/00364	<i>D. alata</i>	2010	33.3
UMUDr-20	TDr 98/00933	<i>D. rotundata</i>	2016	39.8
UMUDr-21	99/Amo/064	<i>D. rotundata</i>	2016	43.9
UMUDa-27	TDa 1100201	<i>D. alata</i>	2019	35
UMUDa-28	TDa 1100316	<i>D. alata</i>	2019	34
UMUDr-29 (Super)	TDr 0900067	<i>D. rotundata</i>	2020	22
UMUDr-30 (Nagode)	TDr 1000048	<i>D. rotundata</i>	2020	24
UMUDa-31 (Wonder)	TDa 1100432	<i>D. alata</i>	2020	43
UMUDr-32 (Favourite)	TDr 1100497	<i>D. rotundata</i>	2022	32.7
UMUDr-36 (SharpSharp)	TDr 1302100	<i>D. rotundata</i>	2024	Not stated in release notice

Compiled from the Nigerian Seed Portal Initiative national variety register (Nigerian Seed Portal Initiative 2024) and IITA release announcements (IITA 2024). Asiedu (breeder line TDr 89/02665) and VA Yam are additional IITA-bred materials in wide demonstration use. Yields are as reported at release and were obtained under research-station or on-farm trial management; they are not directly comparable with farmer-managed yields

Materials and methods

Study area

The study was conducted at five locations along a south–north transect in Oyo State, south-western Nigeria, between latitudes 7°30' N and 9°01' N and longitudes 3°27' E and 4°13' E (Fig. 2). The sites span an elevation range of 219–379 m above sea level and a population gradient from Kishi to Ibadan, the state capital (Table 2).

Table 2
Geographical coordinates, elevation and population of the five survey locations in Oyo State, Nigeria

Location	Latitude	Longitude	Elevation (m a.s.l.)	Population
Saki	8°43' N	3°27' E	219	452,204
Kishi	9°01' N	3°53' E	379	155,510
Ogbomoso	8°08' N	4°13' E	339	655,517
Oyo	7°52' N	3°59' E	323	488,000
Ibadan	7°30' N	3°58' E	275	4,004,000
Coordinates are given in WGS 84				

Climate and soils of the study zone

The transect lies within the derived savanna and southern Guinea savanna agro-ecological zones, classified as Aw (tropical wet-and-dry) under the Köppen system. Rainfall is markedly seasonal, beginning in late March or April and ending in October, and follows a bimodal pattern at the southern sites with a short mid-season dry spell in August that becomes progressively unimodal towards Saki and Kishi in the north. Long-term mean annual rainfall for south-western Nigerian synoptic stations ranges from 1224.7 to 1537.1 mm (1984–2014 NiMet series), while the Guinea savanna zone as a whole averages 1051.7 mm; the transect therefore experiences a decline in rainfall of roughly 200–400 mm from Ibadan to Kishi. Mean monthly air temperature varies little through the year, with minima of about 21–23°C and maxima of about 30–34°C, giving mean annual temperatures of approximately 26.5°C in the derived savanna and 27.3°C in the Guinea savanna.

The soils of the study zone are developed on rocks of the Precambrian Basement Complex and are mapped by the FAO–UNESCO Soil Map of the World as Ferric Luvisols with associated Plinthic Luvisols (unit Lf26-a; renamed Lixisols in the 1989 legend), corresponding to Alfisols in the USDA Soil Taxonomy. They are typically well drained, sandy-loam to sandy-clay-loam at the surface over a clay-enriched argic horizon, and occupy gently undulating terrain with dominant slopes of 0–8%. Inherent fertility is low to moderate: base saturation is relatively high, but organic carbon is low and both nitrogen and available

phosphorus are commonly deficient, so sustained crop production depends on fertiliser and organic amendment. A summary of the environmental characteristics of the study zone is given in Table 3.

Table 3
Long-term climatic and edaphic characteristics of the study zone, Oyo State, Nigeria

Attribute	Description	Source
Agro-ecological zone	Derived savanna in the south (Ibadan, Oyo) grading into southern Guinea savanna in the north (Ogbomoso, Saki, Kishi); Köppen Aw (tropical wet-and-dry)	Agriculture Nigeria (2024); Usman et al. (2018)
Mean annual rainfall	≈ 1250–1500 mm in the southern (derived savanna) part of the transect and ≈ 1050–1250 mm in the northern (Guinea savanna) part. Long-term means for south-western Nigerian synoptic stations range from 1224.7 to 1537.1 mm (NiMet series, 1984–2014); the Guinea savanna zone mean is 1051.7 mm	Obateru et al. (2023); Agriculture Nigeria (2024)
Rainfall regime	Rains from late March/April to October, bimodal in the south with a short “August break”, becoming progressively unimodal northwards; dry season November–March under the north-east trades	Obateru et al. (2023)
Mean temperature range	Mean monthly minima of ≈ 21–23°C and maxima of ≈ 30–34°C; mean annual air temperature ≈ 26.5°C in the derived savanna and ≈ 27.3°C in the Guinea savanna. Highest maxima occur in February–March, lowest in July–August	Agriculture Nigeria (2024); Adeniyi and Oyekola (2023)
Dominant soil type	Ferric Luvisols with associated Plinthic Luvisols (FAO–UNESCO map unit Lf26-a; Lixisols in the 1989 legend), equivalent to Alfisols in USDA Soil Taxonomy. Sandy-loam to sandy-clay-loam surface horizons over a clay-enriched argic B horizon, developed on Precambrian Basement Complex rocks; well drained, low to moderate inherent fertility, low organic carbon, and deficient in N and available P	FAO–UNESCO (1990); FAO (1997)
Relief	Gently undulating basement-complex plain, 219–379 m a.s.l. across the five survey points (Table 2), with dominant slopes of 0–8%	FAO–UNESCO (1990); this study

Full bibliographic details for the sources cited in this table remain to be added to the reference list by the authors

Farmer survey and sampling

A cross-sectional survey was conducted using a structured questionnaire that combined closed items on demographic characteristics, cultivation history and planting-material choice with open-ended prompts allowing respondents to elaborate on the reasoning behind their choices. Respondents were drawn through three registered farmer cooperatives operating in the study area – UI Agrifamily, the Association of Sustainable Seed Producers of Oyo State (ASSPON), and Irepodun-Eniosa – which were

also engaged directly to assess collective awareness of, and participation in, improved-genotype production. Cooperative-level participation was rated on a three-point scale (low, medium, high) using cultivated land area as the quantitative basis: low, 0–2 ha; medium, > 2–4 ha; high, > 5 ha.

Nine farmer groups were surveyed across the five locations, yielding 28 respondents in total. Focus group discussions were held alongside the individual interviews to explore collective knowledge of improved varieties and to cross-check individual responses on genotype identity and local nomenclature.

Genotype inventory and species verification

On-farm accessions were described in situ using the IPGRI/IITA descriptor list for yam (IPGRI/IITA 1997), with minor modifications to the scoring states to reflect the variation encountered (Fig. 3). The purpose of this component was species verification rather than discrimination among landraces: farmer nomenclature alone does not establish species identity, and assigning each named genotype to *D. rotundata*, *D. alata* or *D. cayenensis* is a prerequisite for interpreting the inventory. Qualitative descriptors of this kind are known to carry limited within-species resolution, and no attempt was made to separate landraces on their basis. Descriptor-based characterisation has been applied to yam and related crops across a range of African ecologies (Kouassi et al. 2019; Shitta et al. 2021; Valentine et al. 2020). Twelve qualitative descriptors were recorded, together with planting-material class (1 = landrace, 2 = improved genotype):

- Leaf colour: 1 = green; 2 = very dark green; 3 = very light green
- Leaf arrangement: 1 = opposite; 2 = alternate; 3 = both
- Hair shape: 1 = T-shaped; 2 = simple; 3 = other
- Leaf margin colour: 1 = green; 2 = purple; 3 = other
- Vein colour: 1 = yellowish; 2 = purple; 3 = pale purple; 4 = green
- Leaf shape: 1 = ovate; 2 = cordate; 3 = cordate long; 4 = cordate broad
- Leaf apex shape: 1 = obtuse; 2 = acute; 3 = emarginate
- Tuber skin colour: 1 = greyish; 2 = light brown; 3 = dark brown; 4 = other
- Tuber shape: 1 = round; 2 = oval; 3 = oval-oblong; 4 = cylindrical; 5 = flattened; 6 = irregular
- Root density on tuber surface: 1 = few; 2 = many
- Root position on tuber: 1 = lower; 2 = middle; 3 = upper; 4 = entire tuber
- Maturity class: early, medium, late (farmer-reported and confirmed at harvest)

Genotype identity was established through farmer nomenclature, verified independently with cooperative executives in each location, and species assignment was made on the basis of the descriptor scores. Mean tuber weight was determined by weighing harvested tubers of each genotype on a calibrated field balance.

Data analysis

Questionnaire responses were analysed by descriptive statistics in IBM SPSS Statistics version 27 (IBM Corp., Armonk, NY, USA) and visualised in Microsoft Excel 2021. Paleontological Statistics (PAST version 3.15) was used for the detrended correspondence analysis (DCA) and principal component analysis (PCA). Genotype richness per farmer group was computed from the location $\times$ genotype incidence matrix. Compositional relationships among locations – not morphological relationships among genotypes – were examined by DCA, which reduces the arch and compression artefacts of standard correspondence analysis in gradient data (Hill and Gauch 1980), and by PCA on the same matrix, with locations as observations and genotype presence as variables. Both ordination methods are standard in yam and root-crop diversity studies (Kouassi et al. 2019; Mulualem 2016).

Because the field records document genotype presence rather than counts of individuals, the number of taxa equalled the number of records at every site. Under that structure, Shannon and Simpson indices are monotone functions of richness alone and evenness is fixed at unity by construction. We therefore report genotype richness as the diversity statistic and interpret the index values in Table 5 only as a transformation of richness, not as independent evidence of evenness or dominance.

Results

Characteristics of respondents

Yam cultivation in the study area was male-dominated. Respondents were concentrated in the middle age classes: 46.4% were aged 41–60 years, 32.1% were 21–40 years, and 21.4% were 61 years or older. Farming was the primary occupation of 71.4% of respondents, with the remaining 28.6% combining farming with a secondary occupation. Farming experience was substantial: 42.9% of respondents had more than 20 years of yam-growing experience and 28.6% had 5–10 years (Fig. 4a–c).

Genotypes cultivated and reasons for choice

No respondent cultivated improved genotypes exclusively. The great majority (85.7%) grew landraces only, and the remaining 14.3% grew both landraces and improved material, with landraces occupying the larger share of cultivated area in every such case (Fig. 4d). When asked why, 96.4% of respondents cited satisfactory yield from their landraces. Tradition and the composition of the local seed market were the other dominant reasons: farmers reported growing what has been grown in the area, and what is offered for sale in local markets, because that is what is reliably obtainable at planting time. Respondents who grew landraces exclusively were not, in general, dismissive of improved genotypes; the recurring statement in the focus group discussions was that seed yam of improved genotypes was not available to them to try.

Genotype inventory

Thirty-five genotypes were recorded across the five locations: 24 *D. rotundata*, 9 *D. alata* and 2 *D. cayenensis* (Table 4; Fig. 5). Nine genotypes were classed as of high local abundance among the *D. rotundata* (Ewuru, Tegunde, Okunmado, Gbagidanrin, Dagidagi, Ifegi, Amula, Oju-Iyawo, Bango), together with Isukisu, Ayin and Efuru; four *D. alata* genotypes (Oniyanrin, Ewura Pupa, Egede and Côte d'Ivoire) were similarly abundant. Both *D. cayenensis* genotypes, Iganganran and Lasirin, were of low abundance.

Farmers across all locations named Oju-Iyawo, Ewuru and Tegunde as the preferred *D. rotundata* genotypes and Lasirin as the preferred *D. cayenensis*, although the low abundance and limited commercial cultivation of Lasirin mean that preference did not translate into area. Saki and Kishi shared a broadly similar genotype set. Ibadan differed markedly, and several genotypes recorded there – Ayin, Fere and Efuru – were found only on the farms of growers with more than twenty years of experience, cultivated at subsistence scale.

Two genotypes, Aimo and Ogodo, were reported by farmers to have been common in both fields and markets in previous years but to have declined markedly in recent seasons. Farmers attributed the decline to poor survival of planting material following a period of unfavourable weather, which is consistent with either disease build-up in recycled setts or cumulative degeneration of long-recycled material.

The genotype known locally as Côte d'Ivoire merits separate note. It is a *D. alata* of acknowledged foreign origin, common in the Oyo North area, early maturing, and the most preferred water yam in the zone. Farmers valued it because its cooked flesh resembles that of *D. rotundata* and its tubers are larger than those of other locally known *D. alata*.

Table 4

Species assignment and local abundance of the 35 yam genotypes recorded across five locations in Oyo State

Local genotype name	Species	Abundance class
Ewuru	<i>D. rotundata</i>	High
Tegunde	<i>D. rotundata</i>	High
Okunmado	<i>D. rotundata</i>	High
Gbagidanrin	<i>D. rotundata</i>	High
Dagidagi	<i>D. rotundata</i>	High
Ifegi	<i>D. rotundata</i>	High
Amula	<i>D. rotundata</i>	High
Oju-Iyawo	<i>D. rotundata</i>	High
Bango	<i>D. rotundata</i>	High
Isukisu	<i>D. rotundata</i>	High
Ayin	<i>D. rotundata</i>	High
Efuru	<i>D. rotundata</i>	High
Ihobia	<i>D. rotundata</i>	Low
Aimo	<i>D. rotundata</i>	Low
Ogodo	<i>D. rotundata</i>	Low
Atoja	<i>D. rotundata</i>	Low
Olodo	<i>D. rotundata</i>	Low
Fidio	<i>D. rotundata</i>	Low
Pape	<i>D. rotundata</i>	Low
Fere	<i>D. rotundata</i>	Low
Jebba	<i>D. rotundata</i>	Low
Abuja	<i>D. rotundata</i>	Low
Gudungbu	<i>D. rotundata</i>	Low
Pagi	<i>D. rotundata</i>	Low
Oniyanrin	<i>D. alata</i>	High
Abundance classes defined by cultivated area: low, 0–2 ha; medium, > 2–4 ha; high, > 5 ha. VA Yam was the only improved genotype encountered in the survey		

Local genotype name	Species	Abundance class
Ewura Pupa	<i>D. alata</i>	High
Egede	<i>D. alata</i>	High
Côte d'Ivoire	<i>D. alata</i>	High
Isana	<i>D. alata</i>	Low
Tupe	<i>D. alata</i>	Low
Keregbe	<i>D. alata</i>	Low
Ikokere	<i>D. alata</i>	Low
VA Yam (improved)	<i>D. alata</i>	Low
Iganganran	<i>D. cayenensis</i>	Low
Lasirin	<i>D. cayenensis</i>	Low
Abundance classes defined by cultivated area: low, 0–2 ha; medium, > 2–4 ha; high, > 5 ha. VA Yam was the only improved genotype encountered in the survey		

Genotype richness across locations

Genotype richness per farmer group ranged from 5 to 15 (Table 5). The Ibadan group held the most genotypes (15), followed by the second Saki group (10). The lowest richness was recorded in the second Ogbomoso group (5). As set out in Materials and methods (Data analysis), the Shannon, Simpson and dominance values in Table 5 are deterministic transformations of richness under presence-only recording and carry no additional information; they are reported for completeness and comparability with the wider literature, not as independent evidence.

Table 5
Genotype richness and associated indices for nine farmer groups across five locations

Statistic	KL1	KL2	OYL1	OYL2	OGL1	OGL2	SKL1	SKL2	IBL1
Richness (S)	8	7	9	7	8	5	9	10	15
Records	8	7	9	7	8	5	9	10	15
Dominance (D)	0.125	0.143	0.111	0.143	0.125	0.200	0.111	0.100	0.067
Simpson (1 – D)	0.875	0.857	0.889	0.857	0.875	0.800	0.889	0.900	0.933
Shannon (H')	2.079	1.946	2.197	1.946	2.079	1.609	2.197	2.303	2.708
Evenness (e ^H /S)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Equitability (J)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

KL, Kishi; OYL, Oyo; OGL, Ogbomoso; SKL, Saki; IBL, Ibadan. Suffix denotes farmer group. Evenness and equitability equal unity by construction because richness equals the number of records at every site (see Materials and methods, Data analysis)

Compositional structure across locations

The ordinations below describe how genotype composition varies among locations and form part of the inventory objective; they are not a morphological analysis of the genotypes themselves. Detrended correspondence analysis of the location $\times$ genotype incidence matrix distributed the farmer groups along the first two axes, with a central cluster of groups sharing a common core of widely grown *D. rotundata* genotypes and peripheral positions occupied by groups holding distinctive assemblages (Fig. 6). Groups positioned close together held similar genotype sets; the separation of Ibadan from the northern Oyo groups reflects the presence at Ibadan of genotypes not recorded elsewhere.

Principal component analysis of the same matrix returned a first component accounting for 44.3% of the variation and a second accounting for 26.6%, together explaining 70.9% (Fig. 7). The first component separated locations holding Lasirin, Iganganran, Okunmado, Dagidagi, Ifegi and Gbagidanrin from those holding Tegunde, Ewura Pupa, Côte d'Ivoire, Egede, Isana, Pape, Ogodo, Tupe, Oju-Iyawo, Amula and Oniyanrin. The second component ordered the same two genotype sets in the opposite sense, indicating that the principal axis of compositional variation among locations is the presence or absence of these two coherent genotype groups rather than a gradient in richness.

Species-level diagnostic characters

Species-diagnostic differences were clear and consistent (Table 6, abridged). All *D. alata* genotypes had broadly cordate leaves, brown tuber skin and many surface roots. All *D. rotundata* genotypes had cordate leaves, light brown tuber skin and few surface roots. Both *D. cayenensis* genotypes were early maturing with many surface roots and were the only genotypes on which spines were recorded as present; Iganganran was additionally the sole genotype with alternate leaf arrangement. Within *D. rotundata*, however, the twelve descriptors resolved almost no variation. The 24 genotypes differed from one another in maturity class alone: three were early (Amula, Oju-Iyawo, Efuru), nine medium (Atoja, Olodo, Isukisu, Fidio, Ayin, Fere, Jebba, Abuja, Gudungbu) and eleven late (Ewuru, Tegunde, Okunmado, Gbagidanrin, Dagidagi, Ifegi, Bango, Ihobia, Aimo, Ogodo, Pape). On the remaining eleven characters all 24 accessions scored identically. This uniformity is itself a result, and its interpretation is taken up in the Discussion.

Table 6
Species-level diagnostic key derived from the qualitative descriptors

Descriptor	<i>D. rotundata</i> (n = 24)	<i>D. alata</i> (n = 9)	<i>D. cayenensis</i> (n = 2)
Leaf arrangement	Opposite	Opposite	Opposite (Lasirin); alternate (Iganganran)
Leaf shape	Cordate	Cordate broad	Cordate
Leaf apex	Acute	Acute	Acute
Leaf, margin and vein colour	Green	Green	Green
Hair shape	Simple	Simple	Simple
Tuber skin colour	Light brown	Brown	Light brown
Surface roots	Few	Many	Many
Spines	Absent	Absent	Present
Maturity	Early to late	Early to late	Early

Complete genotype-by-descriptor scores for all 35 genotypes are provided in Online Resource 1

Mean tuber weight

Mean tuber weight was recorded for 27 of the 35 genotypes and ranged from 1.5 to 3.9 kg (Table 7; Fig. 8). Guinea yam genotypes were consistently heavier than water yam genotypes: mean tuber weight among the *D. rotundata* sampled was in the region of 2.7 kg against approximately 1.8 kg among the *D. alata*. The heaviest tubers were recorded for VA Yam, the single improved genotype encountered, at 3.9 kg, followed by the landrace Isukisu at 3.8 kg. The most widely preferred landraces sat in the middle of the range: Oju-Iyawo at 3.1 kg, Ewuru and Tegunde at 3.0 kg. These are per-tuber means and are not directly convertible to area yield, which in white Guinea yam depends jointly on plant density and fertiliser regime (Law-Ogbomo and Osaigbovo 2014).

Table 7
Mean tuber weight of 27 yam genotypes recorded in Oyo State

Genotype	Species	T1 (kg)	T2 (kg)	T3 (kg)	Mean $\pm$ SD (kg)	Variance (kg ²)	CV (%)
Isukisu	<i>D. rotundata</i>	4.29	3.62	3.49	3.80 $\pm$ 0.43	0.184	11.3
Amula	<i>D. rotundata</i>	3.69	3.40	3.11	3.40 $\pm$ 0.29	0.084	8.5
Dagidagi	<i>D. rotundata</i>	3.80	3.48	2.92	3.40 $\pm$ 0.45	0.198	13.1
Gbagidanrin	<i>D. rotundata</i>	3.50	3.26	2.84	3.20 $\pm$ 0.33	0.112	10.4
Oju-Iyawo	<i>D. rotundata</i>	3.36	3.34	2.60	3.10 $\pm$ 0.43	0.188	14.0
Ewuru	<i>D. rotundata</i>	3.39	3.04	2.57	3.00 $\pm$ 0.41	0.169	13.7
Tegunde	<i>D. rotundata</i>	3.26	2.94	2.80	3.00 $\pm$ 0.24	0.056	7.9
Okunmado	<i>D. rotundata</i>	3.31	2.98	2.71	3.00 $\pm$ 0.30	0.090	10.0
Aimo	<i>D. rotundata</i>	2.90	2.81	2.69	2.80 $\pm$ 0.10	0.011	3.8
Ogodo	<i>D. rotundata</i>	2.98	2.88	2.54	2.80 $\pm$ 0.23	0.053	8.3
Atoja	<i>D. rotundata</i>	3.09	2.76	2.55	2.80 $\pm$ 0.27	0.074	9.7
Olodo	<i>D. rotundata</i>	2.61	2.42	2.17	2.40 $\pm$ 0.22	0.049	9.2
Ifegi	<i>D. rotundata</i>	2.06	2.03	1.91	2.00 $\pm$ 0.08	0.006	4.0
Fidio	<i>D. rotundata</i>	1.99	1.84	1.57	1.80 $\pm$ 0.21	0.045	11.8
Ihobia	<i>D. rotundata</i>	1.77	1.59	1.44	1.60 $\pm$ 0.17	0.027	10.3
Bango	<i>D. rotundata</i>	1.57	1.56	1.37	1.50 $\pm$ 0.11	0.013	7.5
VA Yam (improved)	<i>D. alata</i>	4.62	3.79	3.29	3.90 $\pm$ 0.67	0.451	17.2
Côte d'Ivoire	<i>D. alata</i>	2.50	2.39	2.01	2.30 $\pm$ 0.26	0.066	11.2
Egede	<i>D. alata</i>	2.20	2.10	2.00	2.10 $\pm$ 0.10	0.010	4.8
Oniyanrin	<i>D. alata</i>	1.75	1.71	1.64	1.70 $\pm$ 0.06	0.003	3.3
Isana	<i>D. alata</i>	1.87	1.72	1.51	1.70 $\pm$ 0.18	0.033	10.6
Ikokere	<i>D. alata</i>	1.79	1.67	1.64	1.70 $\pm$ 0.08	0.006	4.6
Ewura Pupa	<i>D. alata</i>	1.82	1.60	1.38	1.60 $\pm$ 0.22	0.048	13.7
Keregbe	<i>D. alata</i>	1.72	1.62	1.46	1.60 $\pm$ 0.13	0.017	8.2
Tupe	<i>D. alata</i>	1.64	1.61	1.25	1.50 $\pm$ 0.22	0.047	14.5
T1–T3, individual tubers weighed per genotype. SD, standard deviation; CV, coefficient of variation							

Genotype	Species	T1 (kg)	T2 (kg)	T3 (kg)	Mean $\pm$ SD (kg)	Variance (kg ²)	CV (%)
Iganganran	<i>D. cayenensis</i>	2.95	2.73	2.72	2.80 $\pm$ 0.13	0.017	4.6
Lasirin	<i>D. cayenensis</i>	1.71	1.65	1.44	1.60 $\pm$ 0.14	0.020	8.9
T1–T3, individual tubers weighed per genotype. SD, standard deviation; CV, coefficient of variation							

Demand for improved genotypes

Demand expressed in the focus group discussions was not for information about improved genotypes but for physical access to them. Farmers in every location stated that their principal constraint on trying improved material was obtaining seed yam of it. Cooperative-level assessment corroborated this: participation in improved-genotype production was low across all three cooperatives engaged, including ASSPON, whose stated remit is sustainable seed production. Where farmers had encountered improved material at all, it was the water yam VA Yam, and it was present only in small stands.

Discussion

A landrace-dominated system inside a formally served state

The central result of this study is the near-total absence of improved genotypes from farmers' fields in a state that has been within the operational footprint of national and international yam seed system interventions for over a decade. Twenty-two improved varieties have been released and registered in Nigeria since 2003 with reported yields of 22–44 t ha⁻¹ (Table 1). Across 28 farmers in five established production centres, exactly one improved genotype was encountered, at low abundance. Not a single respondent had replaced landraces with improved material; the 14.3% who grew both maintained landraces on the larger share of their land.

This is consistent with the wider Nigerian picture. Stuart et al. (2021), surveying 122 yam farmers across five states including Oyo, found that almost all varieties named by farmers were landraces and that newly improved varieties appeared only in the fields of farmers who had received them directly through seed projects in 2017. Adoption of released varieties has remained low despite sustained breeding investment (McEwan et al. 2021). It also sharpens the question of mechanism. The available explanations — awareness, trait mismatch, cost, availability — make different predictions about what a survey like this should find, and the pattern here discriminates among them.

Seed access, not farmer conservatism, is the binding constraint

Three lines of evidence in these data point to availability rather than attitude as the operative barrier.

First, the reason farmers gave was availability. In the focus group discussions the recurring statement was not that improved genotypes were unwanted or unsuitable, but that seed yam was not available for them to try. Farmers grew what the local market offered at planting time, a pattern consistent with Stuart et al. (2021), who found that most Nigerian yam farmers source seed off-farm and that the market, rather than any formal channel, is the dominant source. Where the choice set does not contain improved material, no amount of favourable disposition toward it will register as adoption.

Second, the one improved genotype that had reached the study area performed. VA Yam recorded the highest mean tuber weight of the 27 genotypes weighed (3.9 kg), above the best-performing landrace (Isukisu, 3.8 kg) and well above the most widely grown landraces. Yet it was recorded at low abundance in a single location. A genotype that outperforms on the trait farmers say they care about, and that nonetheless fails to spread, is not failing on merit.

Third, and most tellingly, the informal system demonstrably can diffuse novel material when it enters. The genotype farmers call Côte d'Ivoire is an acknowledged foreign introduction of *D. alata* that has reached high abundance across the Oyo North area through farmer-to-farmer exchange alone, without formal release, extension support or a certified seed channel (Fig. 9). Farmers adopted it because its cooked flesh resembles Guinea yam, its tubers are larger than other local water yams, and it matures early. There is a direct precedent. The *D. alata* variety Florido was brought to Côte d'Ivoire from Puerto Rico in the early 1970s for a harvest-mechanisation project that was subsequently abandoned; the variety nonetheless spread rapidly among Ivorian farmers on the strength of its own agronomic and culinary merits, without the support of the national research and extension system (Doumbia et al. 2004). Doumbia et al. (2004) concluded that a variety introduced for entirely the wrong reasons can still diffuse widely if its attributes suit farmers, even in a slowly multiplying tuber crop. The genotype recorded here under the name of its country of origin may well be the same material, or a close relative, arriving in south-western Nigeria by the same informal route. This is a natural experiment in the same farming system: a novel genotype with a favourable trait profile spread rapidly through informal channels, while formally released genotypes with documented yield advantages did not. The difference between the two cases is not farmer receptiveness. It is whether planting material physically entered the exchange network.

The policy implication follows directly. Awareness campaigns and demand creation are necessary but not sufficient, and in this system they are not the first-order constraint. Interventions that increase the volume of seed yam of improved genotypes circulating within existing farmer-to-farmer networks — decentralised multiplication anchored on cooperatives such as ASSPON, community seed enterprises, and the deliberate seeding of local seed markets — target the constraint that this survey actually identified. This is the conclusion Stuart et al. (2021) reach for Nigeria: building on the existing farmer-based system is a more logical strategy than attempting to replace it with formal structures and certification. Informal seed traders have been shown to function as the effective backbone of

smallholder seed supply across Africa (Sperling et al. 2020), and coordination failure between formal and informal segments is a recurring cause of underperformance in root, tuber and banana seed interventions (Almekinders et al. 2019; Bentley et al. 2018). The high-ratio propagation technologies developed under YIFSWA (aeroponics, temporary immersion bioreactors, adapted miniset methods) address the upstream bottleneck; the results here suggest the downstream link from early-generation seed to the local market remains the weak one in Oyo State.

Trait profiles of dominant landraces as breeding benchmarks

The landraces that dominate cultivation in the study area do so for identifiable and largely non-yield reasons, and these constitute a specification that any candidate replacement must meet.

Oju-lyawo, the most widely grown *D. rotundata* across Kishi, Ogbomoso and Saki, is early maturing, commands a good price in the local market and has export value. Its mean tuber weight (3.1 kg) is unremarkable within its species group; its dominance rests on earliness and market acceptance, not on tuber size. Ewuru is late maturing, and farmers retain it deliberately for that reason, because it supplies the late-year market when other genotypes have been sold. Oniyanrin, a *D. alata*, is grown for an industrial outlet – confectionery and biscuit manufacture – despite a low mean tuber weight of 1.7 kg. Water yam varieties differ substantially in the functional and pasting properties that determine suitability for such products (Baah 2009; Udensi et al. 2008), so processing outlets are a legitimate and separable breeding target within the species. Côte d'Ivoire is retained for culinary resemblance to Guinea yam and for earliness.

Earliness, staggered maturity across a farm portfolio, market and export acceptance, and processing suitability are therefore the operative selection criteria in this system, and only the last of these is a conventional yield trait. This aligns with recent work on demand-led yam breeding in Nigeria (Kalu et al. 2023) and with the broader finding that consumer and processing quality, rather than yield, is the dominant driver of varietal change in root, tuber and banana crops (Thiele et al. 2021). It also aligns with the landrace benchmarking approach applied in Benin, where minimum thresholds for yield per mound, tuber dimensions and sensory attributes were derived from the landraces farmers actually grow and proposed as release criteria. Instrumental and sensory descriptors for boiled yam texture and taste are now sufficiently well established to serve as such thresholds (Adinsi et al. 2024), and gender-disaggregated consumer testing has shown that local and new varieties are evaluated on distinct sensory grounds (Effah-Manu et al. 2023). We suggest the same approach be applied to the Oyo State landrace set: Oju-lyawo as the benchmark for earliness plus market acceptance, Ewuru for late-season storage and market fit, and Oniyanrin for processing quality in *D. alata*.

The maturity spread documented here also cautions against a single-variety replacement model. Farmers in the study area maintain early, medium and late genotypes simultaneously, which distributes labour across the season, spreads market risk and extends the period of household food availability. A

high-yielding improved variety that replaces one element of that portfolio may be adopted; one that asks farmers to abandon the portfolio structure will not be.

Signals of genetic erosion

Aimo and Ogodo were reported as formerly common in fields and markets but now scarce, with the decline attributed by farmers to poor survival of planting material after a period of unfavourable weather. Both were still recorded at reasonable tuber weight (2.8 kg each), so the decline is unlikely to reflect an inherent yield deficiency. Farmers in Nigerian yam systems experiment continuously with their own management responses to pest and disease pressure (Ogbonna 2019), and the abandonment of a genotype is more often the end point of that process than a first reaction. The more probable mechanisms are pathogen build-up in long-recycled setts, or cumulative degeneration of vegetatively propagated material, either of which is exacerbated by climatic stress. Vegetative propagation from farmer-saved tubers makes yam particularly vulnerable to this form of attrition (Aighewi et al. 2015). Independent corroboration comes from Oyo State itself: Stuart et al. (2021) recorded a seed seller reporting that the older varieties Lasinrin and Olodo had been abandoned altogether, and that farmers replace a seed lot whenever a variety ceases to yield or becomes diseased. Both genotypes were still present, at low abundance, in the present survey — Lasirin as a *D. cayenensis* preferred by farmers but barely cultivated, and Olodo at 2.4 kg mean tuber weight. Read together, the two studies suggest an attrition process already well advanced.

A related pattern was visible at Ibadan, where Ayin, Fere and Efuru were found only on the farms of growers with more than twenty years of experience, cultivated at subsistence scale as those growers reduce their operations with age. These genotypes are one generation from local extinction. Both observations argue for the collection and ex situ conservation of the Oyo State landrace set, and for the inclusion of declining genotypes in national genebank holdings before the knowledge that accompanies them is lost with the growers who hold it.

Demographic patterns

The demographic profile of respondents is consistent with the wider literature on yam production. Male dominance in yam cultivation has been attributed to the labour intensity of mounding and staking, gendered patterns of land ownership and decision-making, and the association of yam farming with social prestige and cultural identity for men (Obidiegwu and Akpabio 2017). Stuart et al. (2021) report the same asymmetry quantitatively: despite deliberate efforts to recruit a gender-balanced sample, only 22% of the yam farmers they interviewed were women, while women made up 86% of yam sellers who did not themselves farm. The concentration of respondents in the 41–60 age class, and the finding that 42.9% had more than twenty years of experience, sits alongside a body of work reporting that older and more experienced farmers are more risk-averse toward new varieties, more likely to persist with previous varietal decisions, and more attached to the diversity, resilience and cultural significance of landraces. Other work qualifies this, finding that experienced farmers do adopt improved genotypes where

information, extension services and markets are reliably available, often using improved material to complement rather than replace their landraces.

The present data cannot adjudicate between these positions, and we do not attempt to. A contingency test comparing the four respondents who grew some improved material against the twenty-four who grew none is arithmetically possible, and with four cases concentrated in a single class it could even return a conventionally significant P value. We consider such a test uninformative and have not run it. It would contrast farmers who grow a little improved material with farmers who grow none, which is not adoption against non-adoption, since no respondent had adopted; with four cases in one cell the result turns on a single classification; and, decisively, it could not separate age from availability, because twenty-four of the twenty-eight respondents were never exposed to the option whose refusal the test would be attributing to their age. We therefore note the demographic profile as context for the sampling frame rather than as an explanation of the adoption pattern, which is better accounted for by seed availability.

What the descriptor uniformity implies

Twenty-four farmer-named *D. rotundata* genotypes scoring identically on eleven of twelve qualitative characters admits two readings, and they carry different consequences.

The first is methodological: qualitative descriptors are simply too coarse to separate closely related Guinea yam landraces, and the uniformity reflects the instrument rather than the material. This is the conservative reading and is consistent with the general experience that leaf and tuber descriptors discriminate well between *Dioscorea* species but poorly within them.

The second is substantive: some of the 24 names may denote fewer genetically distinct genotypes than the count of names suggests. Farmer nomenclature can over-differentiate, with a single clone acquiring separate names in separate localities or markets. There is direct support for this in the Nigerian yam system. Stuart et al. (2021) noted that because different names may be applied to the same variety, the true number of Nigerian yam varieties is probably lower than the number of names in circulation, and identified Oju-iyawo, Meccakusa and Hembakwase as one variety carrying three regional names. Oju-iyawo is among the most widely grown genotypes recorded in the present study, which places at least one of our accessions inside a documented synonymy.

The two readings are not mutually exclusive and cannot be separated morphologically. They are separable with markers: SSR or DArTseq genotyping of the 35 accessions would establish how many distinct genotypes the Oyo State landrace set actually contains, and would identify synonymy where it exists. Amplified fragment length polymorphism (AFLP) and related marker systems have resolved within- and between-species structure in *Dioscorea* germplasm where morphology alone could not (Sonibare et al. 2010; Tamiru et al. 2007). We regard this as the highest-value follow-up to the present work, with consequences beyond taxonomy: a conservation programme that treats synonymous names

as distinct accessions will over-count the diversity it is protecting, and a breeding programme benchmarking against landraces needs to know which named landraces are genuinely different material.

Conclusions

Across five established yam-growing centres of Oyo State, farmers cultivate a rich portfolio of 35 landrace genotypes spanning three *Dioscorea* species and a deliberate spread of maturity classes, and they cultivate almost nothing else. Twenty-two improved varieties have been released in Nigeria since 2003 with reported yields two to four times what farmers currently achieve, but only one improved genotype was found in the field, at low abundance, in a single location, despite recording the highest mean tuber weight of every genotype weighed.

The evidence assembled here points to seed availability rather than farmer disposition as the operative constraint. Farmers named availability as their barrier; the improved genotype that did reach them performed well on the trait they prioritise and still failed to spread; and a foreign landrace with no formal release, no extension backing and no certified seed channel spread to high abundance in the same system through farmer-to-farmer exchange alone. The informal network can and does diffuse novel genotypes. What it has not been given is improved material to diffuse.

Three actions follow. Decentralised seed yam multiplication should be anchored on the cooperatives that already structure farmer-to-farmer exchange in the state, so that improved genotypes enter the local seed markets from which farmers actually source. Breeding targets should be benchmarked against the trait profiles of the landraces that dominate here – earliness and export acceptance (Oju-Iyawo), late-season market fit (Ewuru), processing suitability (Oniyanrin) – rather than against yield alone, and should respect the portfolio structure of maturity classes that farmers maintain. And the Oyo State landrace set should be collected and conserved without delay, with priority given to Aimo and Ogodo, which farmers report as declining, and to Ayin, Fere and Efuru, which survive only on the shrinking farms of the oldest growers.

Declarations

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Competing interests

The authors have no relevant financial or non-financial interests to disclose.

Ethics approval

Participation in the survey was voluntary. All personal identifiers were removed prior to analysis and no individual-level data are reported. A farmers' liaison officer was present at each study location.

Consent to participate

Verbal informed consent was obtained from every respondent prior to interview, following an explanation of the study's purpose and the intended use of the data. Respondents were informed that they could decline any question or withdraw at any point.

Consent to publish

Figure 3a contains a photograph in which an individual is visible. Written informed consent for publication of this image was obtained from the individual concerned.

Data availability

The anonymised dataset generated and analysed during the current study is not publicly available in order to protect the privacy of survey respondents, but is available from the corresponding author on reasonable request.

Author contributions

Conceptualisation: Abolade Lawrence Olanrewaju, Morufat O. Balogun; Methodology: Morufat O. Balogun, Rasheed O. Awodoyin, Beatrice A. Aighewi; Investigation and data curation: Abolade Lawrence Olanrewaju; Formal analysis: Abolade Lawrence Olanrewaju; Writing — original draft preparation: Abolade Lawrence Olanrewaju; Writing — review and editing: Morufat O. Balogun, Rasheed O. Awodoyin, Beatrice A. Aighewi; Supervision: Morufat O. Balogun, Rasheed O. Awodoyin, Beatrice A. Aighewi; Resources: Beatrice A. Aighewi; Funding acquisition: Morufat O. Balogun, Beatrice A. Aighewi. All authors read and approved the final manuscript.

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Figures

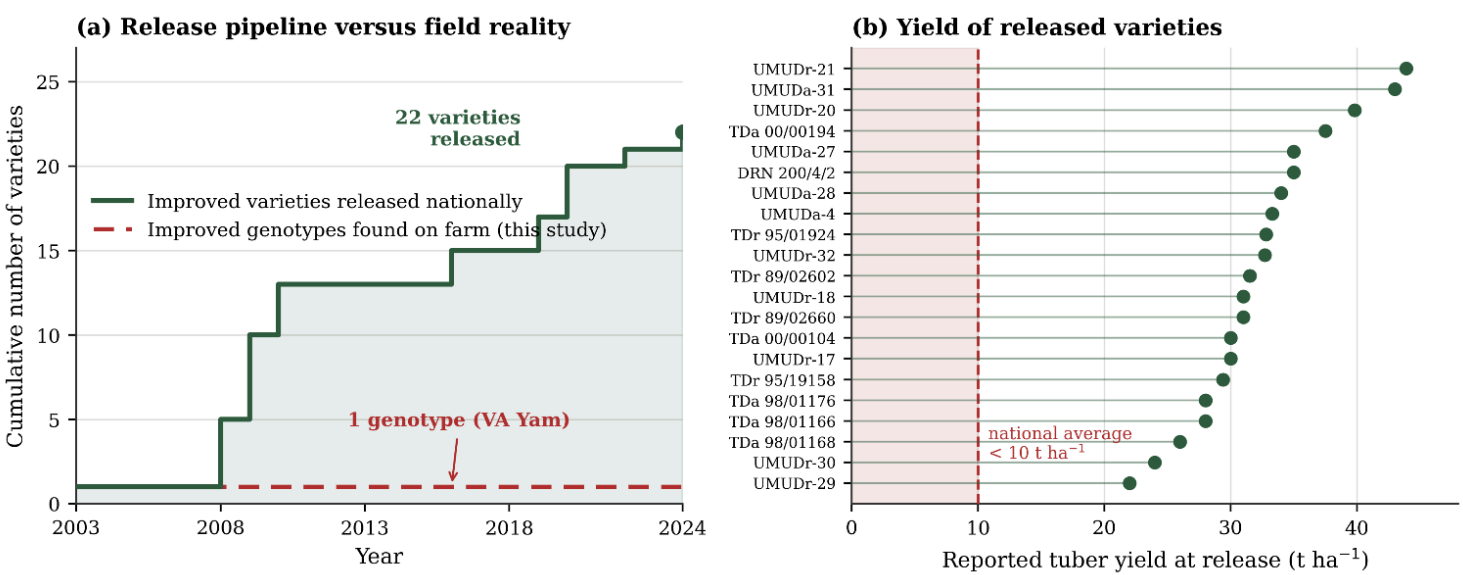


Figure 1

The gap between the release pipeline and the field. **a** Cumulative number of improved yam varieties formally released and registered in Nigeria, 2003–2024 (n = 22), against the number of improved genotypes recorded on farm in this study (n = 1). **b** Reported tuber yield at release for 21 varieties with published figures, against the national average yield of below 10 t ha⁻¹ (shaded). Yields at release were obtained under research-station or trial management and are not directly comparable with farmer-managed yields

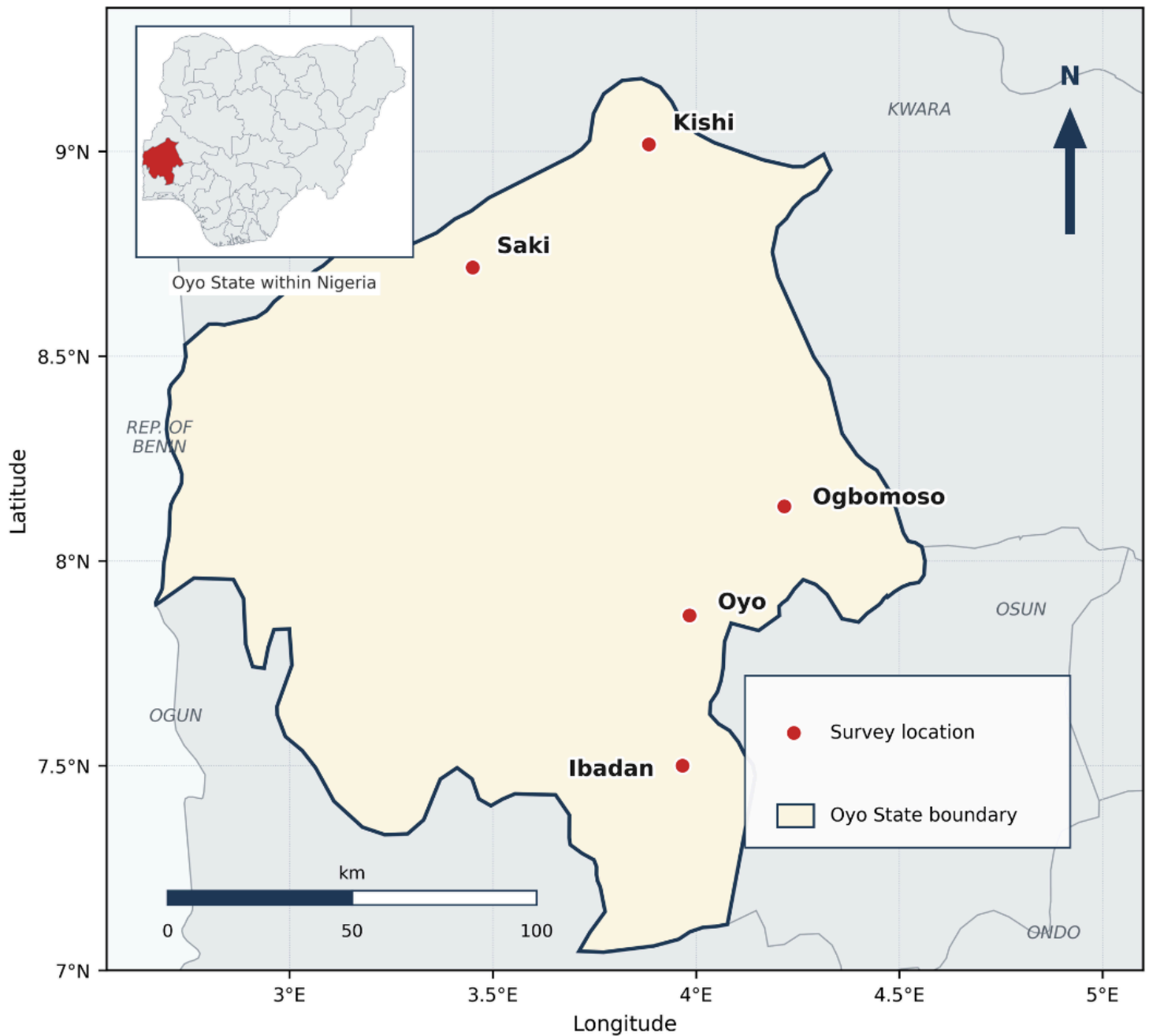


Figure 2

Map of Oyo State, south-western Nigeria, showing the five survey locations (Saki, Kishi, Ogbomoso, Oyo and Ibadan). The inset shows the position of Oyo State within Nigeria. Administrative boundaries after Natural Earth 1:10 m admin-1 dataset (v5.1.1); geographic coordinates, WGS 84



Figure 3

Field characterisation in Oyo State. **a** Staked yam plants showing the vine and leaf characters scored. **b** Harvested tubers of a landrace genotype in situ. **c** Determination of tuber weight in the field. Photographs by the first author

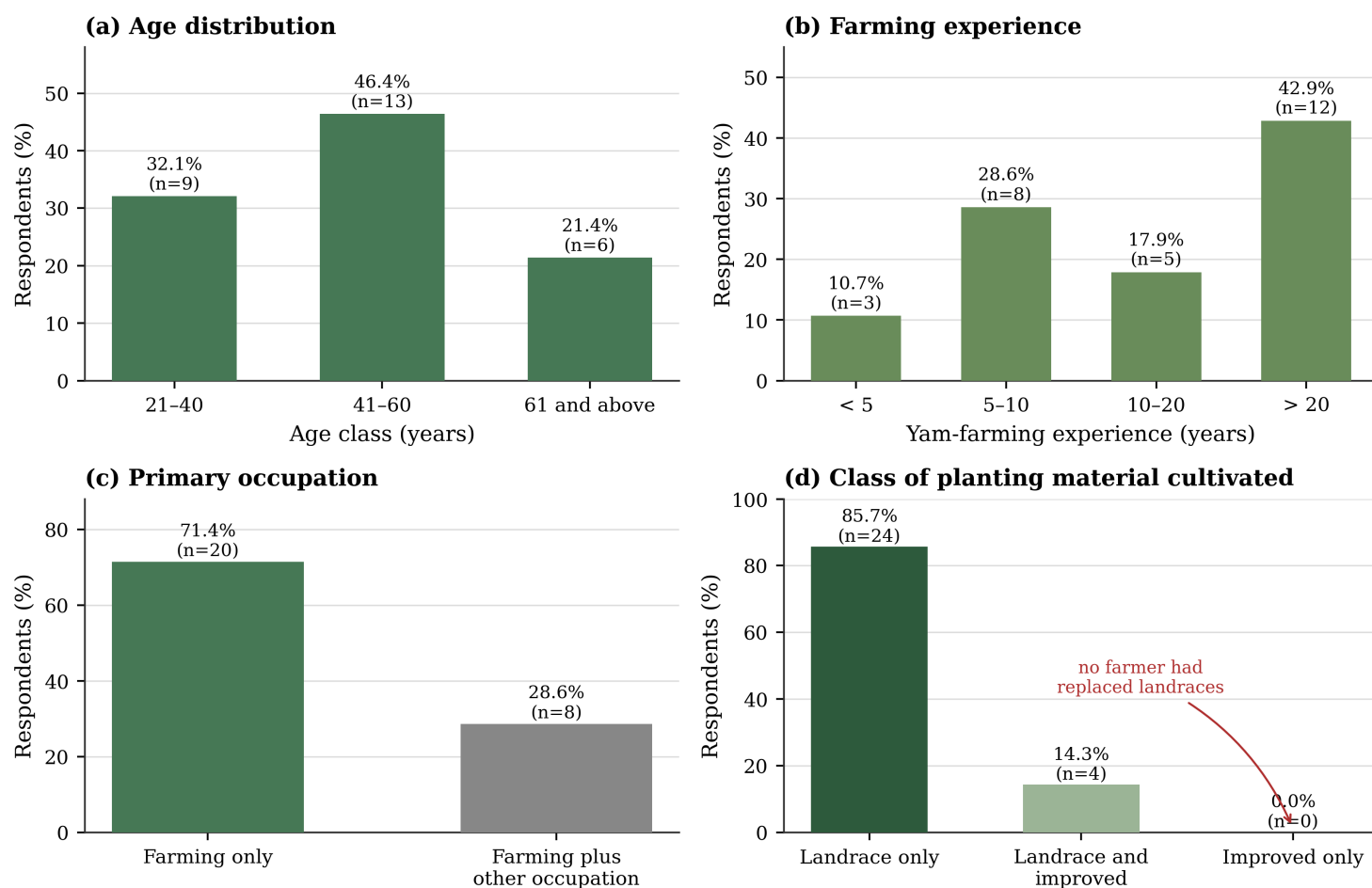


Figure 4

Profile of survey respondents (n = 28). **a** Age distribution. **b** Years of yam-farming experience. **c** Primary occupation. **d** Class of planting material cultivated. No respondent cultivated improved genotypes

exclusively

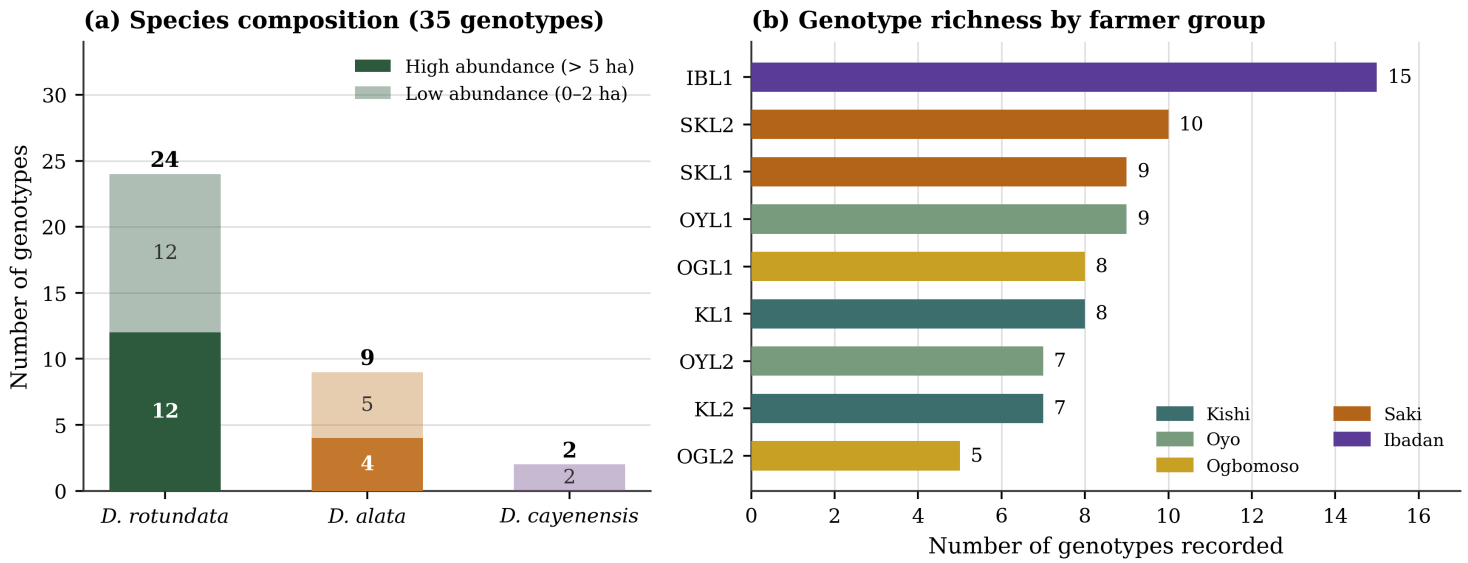


Figure 5

Genotype inventory across the study area. **a** Species composition of the 35 genotypes recorded, partitioned by local abundance class. **b** Genotype richness recorded by each of the nine farmer groups, coloured by location

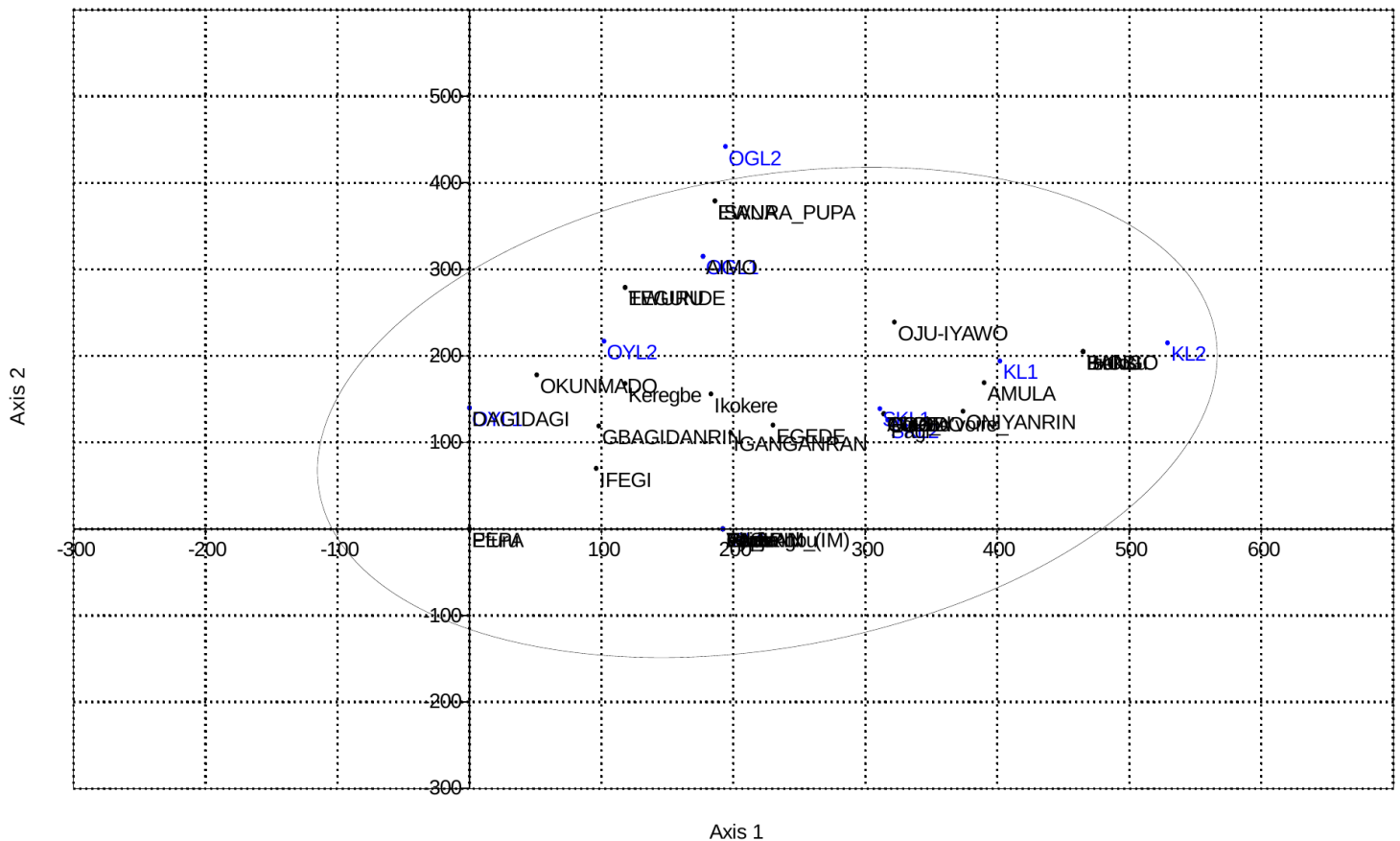


Figure 6

Detrended correspondence analysis of the location × genotype incidence matrix. Farmer groups are shown in blue and genotypes in black; the ellipse encloses the central cluster of groups sharing a common core of widely grown genotypes

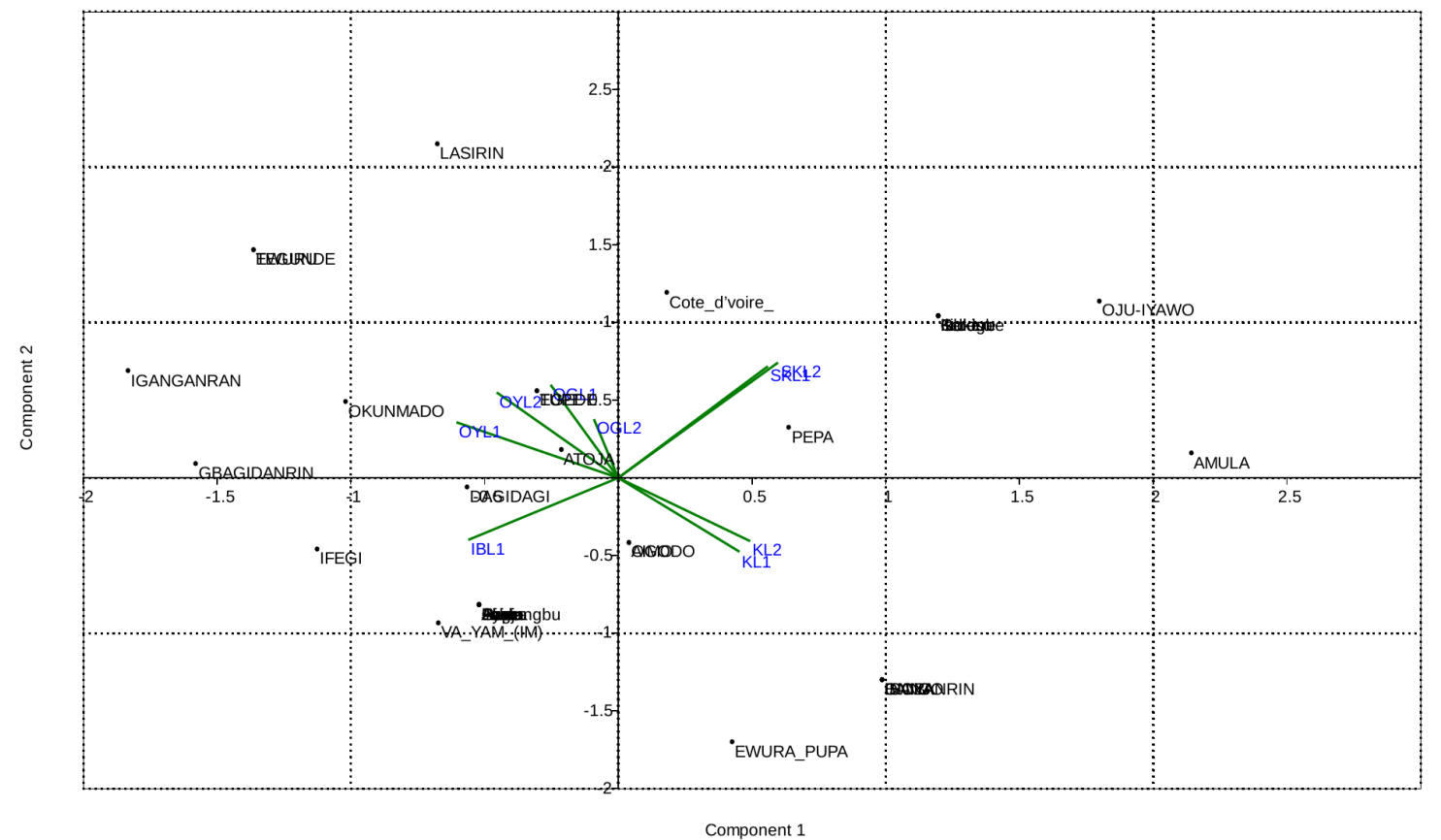


Figure 7

Principal component analysis of the location × genotype incidence matrix. PC1 and PC2 account for 44.3% and 26.6% of the variation respectively (70.9% cumulative)

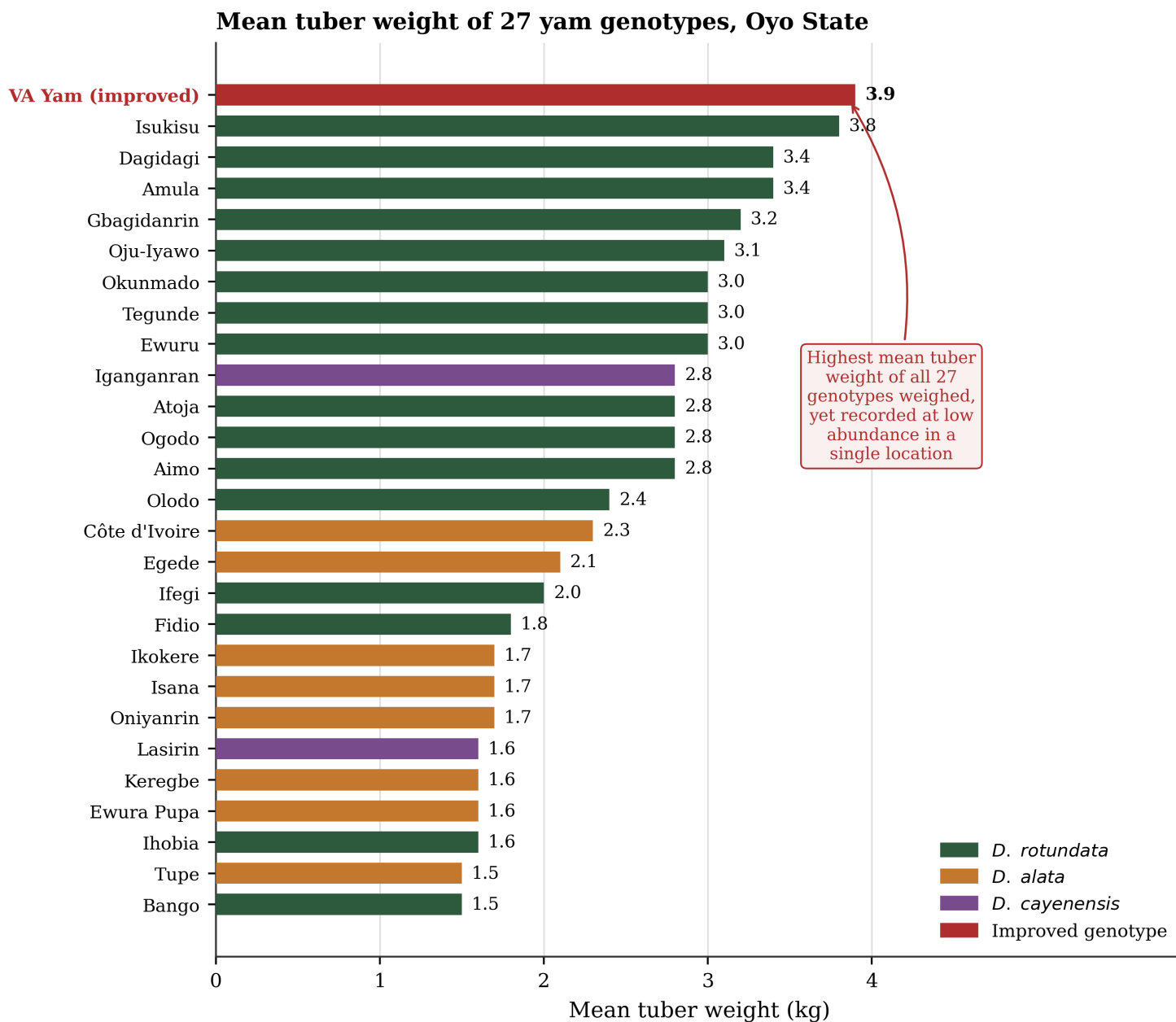


Figure 8

Mean tuber weight of 27 yam genotypes recorded in Oyo State, ordered by weight and coloured by species. VA Yam, the single improved genotype encountered, recorded the highest mean tuber weight of any genotype weighed yet was present at low abundance in one location only

Image not available with this version

Figure 9

Two diffusion pathways operating in the same farming system. Formal pathway: breeding (IITA/NRCRI) → 22 varieties released 2003–2024 → seed yam multiplication → delivery bottleneck → 1 genotype on farm (VA Yam, low abundance). Informal pathway: introduction from Côte d'Ivoire → no formal release → farmer-to-farmer exchange and local markets → high abundance across Oyo North. Formally released varieties reached farmers' fields in one instance only, at low abundance; an unreleased introduction from Côte d'Ivoire reached high abundance across Oyo North through farmer-to-farmer exchange and local seed markets alone. The contrast locates the constraint at seed delivery rather than farmer receptiveness

Supplementary Files

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- [Olanrewaju et al Supplementary Material.docx](#)