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Supply- and Demand-Side Factors Affecting Maize and Cowpea Varietal Turnover and Quality Seed Use

Mixed-Method Evidence from Northern Nigeria

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Abstract

This study provides an integrated assessment of the seed system for maize and cowpea, two of the most important crops in Nigeria. We analyze the various factors influencing seed supply and demand and present different measures of capacity and incentive of multiple actors along the seed value chain. We also present metrics on adoption of improved varieties and quality seed use, given the complexity of these concepts and persistent challenges in measuring them in a survey context. At the national level, the 2015 to 2018 Living Standards Measurement Survey data show that the adoption rate of improved varieties was 16 percent of maize area and 6 percent of cowpea area, with 9 percent of maize farmers and 3 percent of cowpea farmers reporting certified seed use of improved varieties. Data from household surveys conducted in 2022 show that in Bauchi and Kaduna—states with relatively high maize and cowpea production levels—the adoption rate of quality seeds of improved varieties was 10 percent of cowpea land area and 25 percent of maize land area. In addition, the improved varieties in the cowpea and maize plots were old; the area-weighted varietal age in cowpea farms was 12 years and in maize farms, 13 years. The most popular cowpea variety was Kananado (likely matching released variety SAMPEA 9 or SAMPEA 11, released in 2005 and 2009, respectively), and the most popular maize variety was SAMMAZ 15, released in 2008. Newer varieties have not caught up in popularity.

Different stages of the seed value chain face major bottlenecks. Two major themes emerged as barriers and drivers of adoption of newer improved varieties and quality seed: (1) Seed supplies were limited, especially breeder and foundation seeds, implying that Nigeria's seed system needs to increase coordination, funding, and capacity for early-generation seed production and management; and (2) new varieties were not promoted to farmers, who therefore lacked exposure to the seeds, implying that both public and private sectors need to invest more in the promotion of these varieties and increase exposure and testing among farmers. There is also a need to look at the breeding and offerings of newer improved varieties. Some newer varieties do not consistently and comprehensively outperform older bred varieties in field trials and farm demonstrations; some older bred varieties remain attractive and popular to farmers.

Beyond seeds, several contextual factors disabled farmers' and seed actors' capacity and incentive to expand production and adopt improved varieties. Security issues; poor soil conditions; and high fertilizer, transportation, irrigation, and diesel costs were some of the major disablers in the seed system that must be addressed.

Key words: quality seeds; improved varieties; seed system; varietal adoption; maize; cowpea

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1. INTRODUCTION

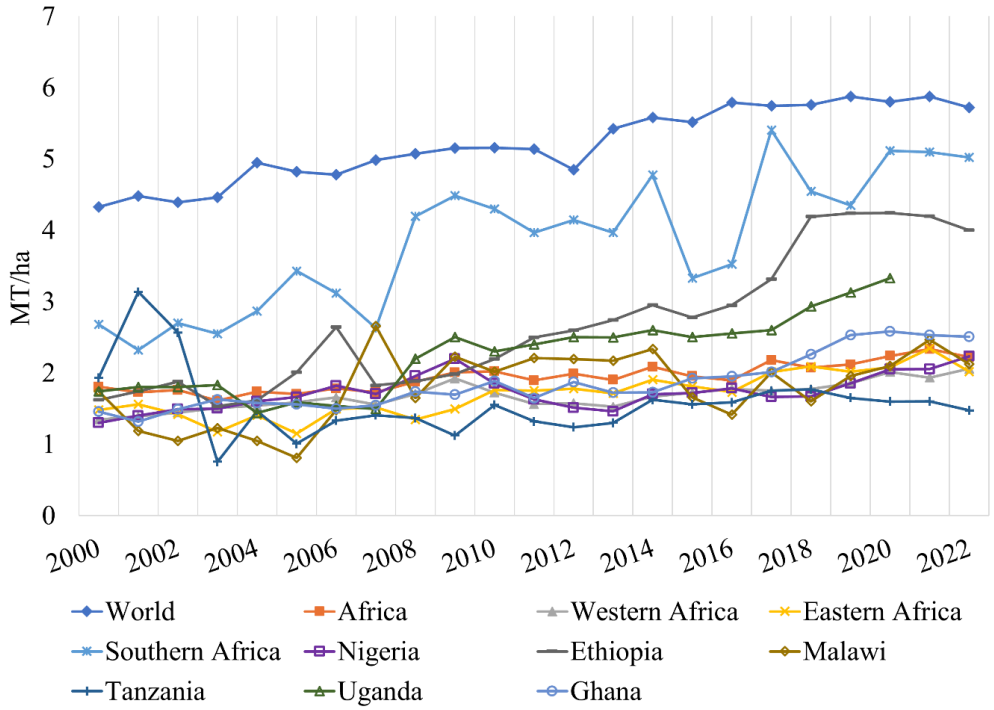
Improved varieties, cultivars, breeds, and quality seeds play a pivotal role in increasing agricultural productivity, improving farmers' livelihoods, and addressing the challenges of climate change and malnutrition. While significant advances have occurred in the development of improved varieties or cultivars over the last decades, their scaling into widespread use has been mixed (Almekinders et al. 2019; Eriksson et al. 2018; McEwan et al. 2019; Walker and Alwang 2015). Significant challenges remain in achieving widespread adoption by smallholder farmers in many low- and middle-income countries. In Nigeria, the 2015 and 2018 Living Standards Measurement Survey data show that only 16 percent of land maize area, 14 percent of land rice area, and 6 percent of land cowpea area were planted with improved varieties, while certified seed use was reported by only 9 percent, 7 percent, and 3 percent of maize, rice, and cowpea farmers, respectively. The challenges identified by past studies are numerous, including supply-side issues from the research and development (R&D) stage through the seed production and distribution stages, as well as demand-side issues that include farmers' preferences, beliefs, and adoption behavior, which affect cultivar and quality seed demand.

Previous studies have highlighted the need for a more integrated understanding of seed systems as a whole and more holistic research that better captures the real-life context and perspectives of farmers and other seed actors while providing the metrics needed by seed system decision-makers and policymakers to enable informed decision-making. This integrated approach is needed to better capture and understand the complex and dynamic nature of farmers' and seed entrepreneurs' reality and experiences along the seed value chain.

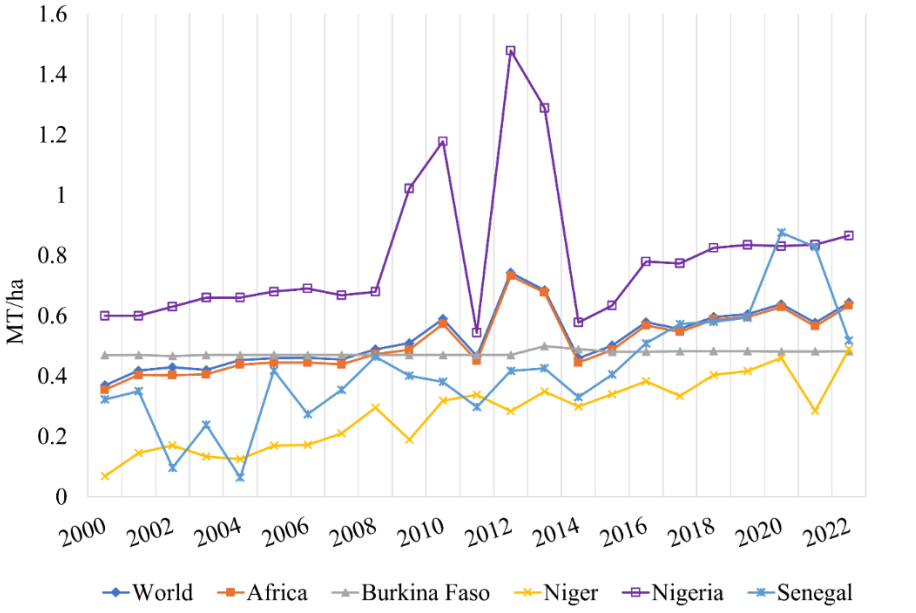
This paper applies an integrated assessment approach to analyzing the seed system in Nigeria, including a deep dive into northern Nigeria, thereby illustrating the types of indicators, data, and analysis needed to capture different actor perspectives along the seed value chain. We implemented this approach in Nigeria, the most populous country in Africa, because it confronts major food and nutrition challenges but also has great potential to transform its seed and agrifood systems.

Two important staple crops in the country are maize and cowpea, but these crops persistently have low productivity: The average maize yield was 1.98 metric tons per hectare (MT/ha) in the last three years, compared to 4.2 MT/ha in Ethiopia and about 5 to 6 MT/ha on average in southern Africa and globally (FAOSTAT; see Figure 1a) and 6-9 MT/ha potential yield in multi-location trials. Nigeria is the world's largest cowpea producer and consumer, but productivity has been growing slowly, reaching only 1.5 percent annually in the last two decades and 0.83 MT/ha in the last three years (FAOSTAT; Figure 1b). This growth is much lower than a potential grain yield achievable at more than 2 MT/ha (Boukar et al. 2018). Low productivity in these crops is reportedly due to poor soil condition, low fertilizer use, poor rains, poor management practices, and low adoption of improved varieties and certified seeds. Expansion in maize production from 1960 to 2020, reported by Wossen et al. (2023), was mainly driven by land area expansion and extensification and much lower growth from yield or productivity improvements.

Figure 1. Maize and cowpea productivity (metric tons per hectare)
A: Maize



B: Cowpea



Source: FAOSTAT. 2021 and 2022 data are estimates.
Note: MT/ha = metric tons per hectare.

Several seed initiatives that have been implemented show mixed outcomes and results (see Ojiewo et al. 2020; Olomola 2015; Onumah et al. 2021; Spielman et al. 2021; Wossen et al., 2023). These include SeedCodex, an electronic seed authentication tag for quality assurance through tracking and traceability; the Seed System Development Project of the Alliance for Green Revolution in Africa (AGRA) and

International Institute of Tropical Agriculture (IITA), which provides capacity building and technical support to certification officers and local seed companies; the Cassava Seed System Reform Policy; the Accelerated Varietal Improvement and Seed Delivery of Legumes and Cereals in Africa project (Nigeria is one of the focus countries); and the Collaborative Seed Programme under the Nigeria–Netherlands Seed Partnership (see Annex 1 for the evolution of the policy and regulatory framework and programs for Nigeria's seed system).

Several government policies and research and extension programs have contributed to the large number of maize varieties released and the growth in maize production. Among these are Operation Feed the Nation, promoting seed and fertilizer use through subsidies; the National Accelerated Food Production Program; the Presidential Initiative on Doubling Maize Production and the Drought Tolerant Maize for Africa (DTMA) project, which supported more than 25 new stress-tolerant and high-yielding maize hybrids and open-pollinated varieties released and promoted to farmers across all the major maize-producing states of the country; and the Agricultural Transformation Agenda and Growth Enhancement Support scheme, which provided a 50 percent subsidy on two bags of fertilizer and up to a 90 percent subsidy on a bag of improved maize and rice seeds that reached more than 4.1 million farmers in 2013 and 7.2 million farmers in 2014 (Fajemisin 2014; Olomola 2015; Wossen et al. 2023).

While documents from these seed projects and initiatives show outputs and achievements, there is little assessment of the systemic development impacts of their interventions. Few available data show sustained progress in adoption of improved varieties and quality seeds, productivity growth, or agricultural transformation. Wossen et al. (2023) describe the productivity growth and transformation of the maize sector in Nigeria since the 1960s, but maize productivity levels and growth are far from those reached during the Green Revolution or those recently achieved in Ethiopia (Bachewe et al. 2018), southern Africa, and globally (Figure 1; Ragasa et al. 2022).

Several studies also examine seed system development and varietal adoption partners and trends in Nigeria in considerable depth (see Manda et al. 2020; Ojiewo et al. 2020; Oyinbo et al. 2019, 2022; Oyetunde-Usman, Olagunju, and Ogunpaimo 2021; Spielman et al. 2021; Wossen et al. 2023). Many adoption studies correlate demographics with adoption; for example, common significant factors found in studies are age of household head, gender, education, household size, access to extension services, and household wealth status (see Oyetunde-Usman, Olagunju, and Ogunpaimo 2021). But often, these findings are not helpful in informing targeting strategies and entry points for interventions. This paper aims to complement past studies with a more integrated understanding of the maize and cowpea seed system and farmers' and other seed actors' real-life decisions about and behaviors toward varieties and seeds. We examine the evolution of the seed system and its contribution to Nigeria's changing maize sector, analyze the cowpea sector and its seed system, and draw comparisons with maize.

We specifically aim to answer the following research questions:

1. What are the drivers and the barriers in varietal uptake for female and male farmers? These include questions about observed patterns and trends in adoption rates of improved maize and cowpea varieties and quality seed, as well as the factors affecting farmers' seed and varietal choices, including preferences and constraints.
2. What are the key policy and implementation challenges and options in the seed sector? This covers issues such as how to enhance the reach and benefit of improved varieties and quality seed, especially for farmers in remote areas of Nigeria.
3. What business models do private sector actors and nongovernmental organizations (NGOs) adopt to promote new varieties, and what are the constraints in replicating and scaling these models?
4. Finally, what socially inclusive and culturally sensitive strategies could be pursued to accelerate varietal turnover?

2. CONCEPTUAL FRAMEWORK

In many crops and contexts, seed has been highly commercial, and private sector investments and the number of seed companies have increased over time. Nonetheless, for some crops and in some contexts, the seed system is characterized by thin and imperfect markets and high transaction costs. One of the factors that determines the existence of a market-driven seed system is the "effective demand" for fresh seed by farmers. The low volume and frequency of purchase of improved varieties are often cited as major reasons for the lack of private sector involvement in seed provision. In the case of open-pollinated crops such as maize, hybridization (which requires repeated purchase of seeds to maintain crop yield) has made private sector involvement possible in the seed system. However, this is not the case for self-pollinated legume crops like cowpeas, because hybridization is not an option. Also, because self-pollination produces progenies that are more uniform than those that result from outcrossing, it is easier for farmers to save some grain from their own harvest to use as seed in the following season. In the case of poor agricultural practices and poor seed management practices, however, breeders and seed actors recommend replacing cowpea seeds every three years to maintain genetic purity and vigor. For open-pollinated varieties (OPVs) of maize, breeders and seed actors recommend replacing seeds every two years. Incentives for private sector involvement in the seed system for OPV maize and legume crops are low, but these encouragements of regular seed replacement, if followed, can improve these incentives.

Other factors undermining a market-driven seed system are transaction costs, search costs, and information asymmetries, which can be high for both buyers and sellers. On the one hand, farmers (as buyers) incur the costs of acquiring reliable information about new varieties. They also face the moral hazard of being sold poor-quality seed, which may become apparent only after the seeds are planted and it is too late to rectify the damage or to seek redress from the seed vendor. Suppliers, on the other hand, encounter high costs of information in discovering farmers' preferences, face the risk of potentially unsold inventory, and must carry stocks to meet uncertain and fluctuating demand. There are high risks involved on both sides. As a result, the market for improved varieties is markedly imperfect and leads to low effective demand, low availability of seeds, and high prices in many contexts. These are most prominent in remote areas, characterized by thin markets, weak infrastructure, and low market incentives. The result is that farmers in developing countries continue to grow crops using low-quality planting material. For example, according to nationally representative data from the Integrated Surveys on Agriculture (ISA), available online for Ethiopia, Malawi, Niger, Nigeria, Tanzania, and Uganda, the use of purchased seed for key legume crops (common bean, cowpea, pigeon pea, and fava bean) produced in these countries is less than 5 percent (Maredia et al. 2019). More than 95 percent of legume seeds planted by smallholder farmers in these countries are recycled seeds saved from their own harvest (60–70 percent) or purchased as grain from other farmers or grain vendors (25–35 percent) (Maredia et al. 2019).

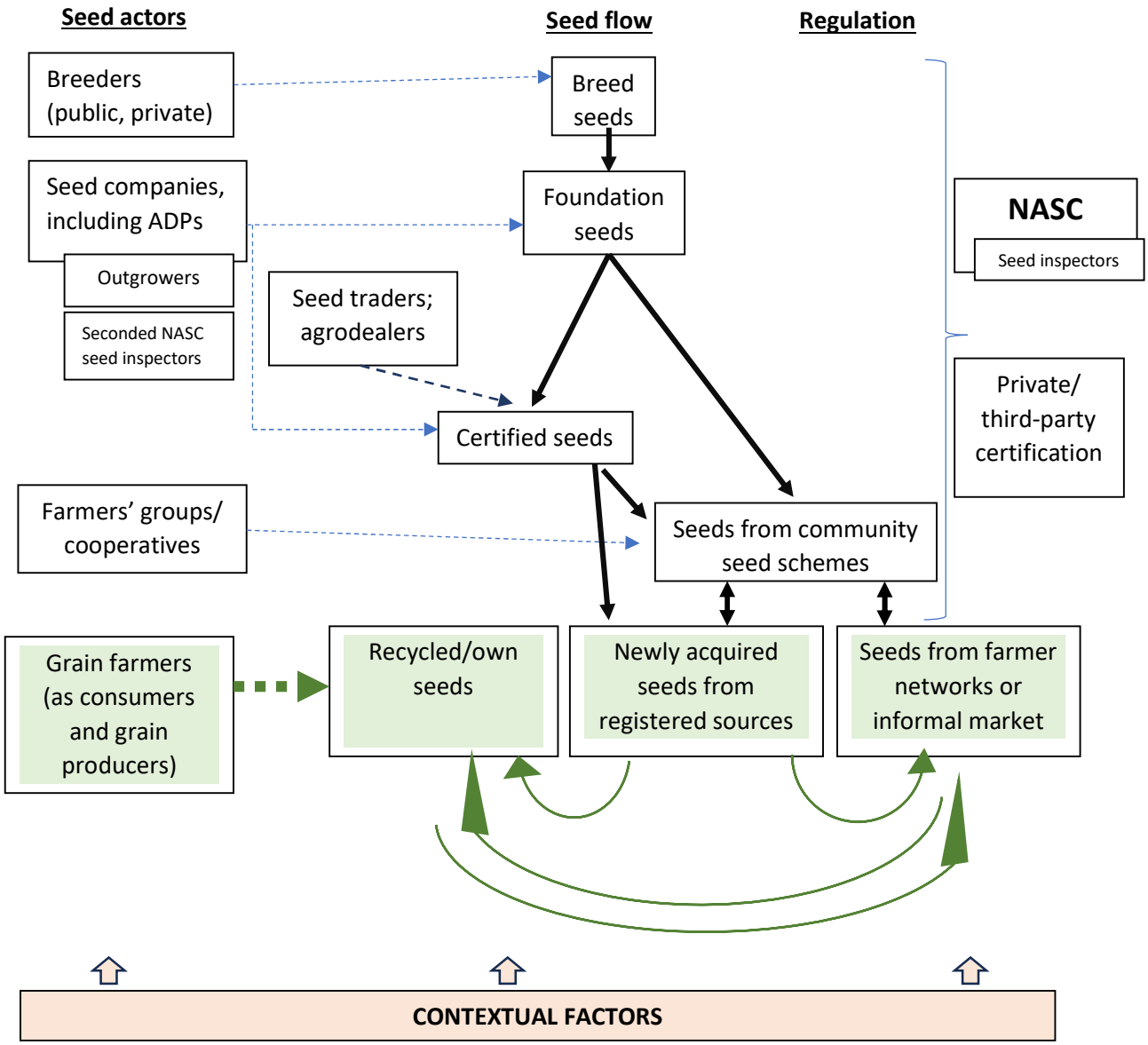
A market-driven seed system requires the coexistence of several demand- and supply-side conditions. Necessary conditions on the demand side are that farmers should be able to perceive the seed product as a higher-quality planting material than grain, are willing to pay a premium for this higher-quality product, and are willing to buy new seeds regularly. On the supply side, the required conditions are that the price farmers are willing to pay must be high enough to cover the cost of producing quality seed, and that the quantity and frequency of seed demanded (that is, seed replacement) at that price are large enough to attract suppliers to produce and sell seeds and to cover risks and uncertainties.

We examine several of these concepts within northern Nigeria's maize and cowpea seed system. First, we differentiate between supply- and demand-side factors. Supply-side factors look at contextual, organizational, and economic factors that affect seed suppliers' and seed producers' ability to produce quality seeds, as well as seed policies, regulations, coordination, and promotion. Demand-side factors look at the grain producer's conditions, capacity, behavior, and preferences that influence their choices and use

of improved varieties and quality seeds. Second, we differentiate between the capacity and incentives of various actors. Capacity includes the ability of seed actors to produce, deliver, and demand seeds. Incentives include financial or economic incentives to produce, deliver, or demand seeds. This concept includes both intrinsic and extrinsic motivation, as well as behavior and preferences that influence seed actors' choices and use of improved varieties and quality seeds. Lastly, we differentiate between economic, informational, cultural/normative, or behavioral factors affecting adoption decisions by farmers. This differentiation can help unpack the specific constraints and potential solutions and strategies to improve varietal turnover and quality seed use.

We apply these concepts to analyze different stages of the seed value chain and identify the bottlenecks in each of the stages (Figure 2).

Figure 2. Seed value chain, Nigeria



Source: Authors.
Note: denotes the actor and the producer of a seed type, denotes a trader, denotes transformation of the seed from pure breeder seed to seeds in farmers' field, denotes movement of farmers' seeds, denotes farmers' use of seeds, and denotes contextual factors (enablers and disablers) affecting the seed system.
ADP = agricultural development program; NASC = National Agricultural Seeds Council.

3. METHODOLOGY

This study used various data sources. First, we reviewed nationally representative surveys (General Household Survey or Living Standards Measurement Study – Integrated Survey on Agriculture [LSMS-ISA], four waves [2010/11, 2012/13, 2015/16, 2018/19]). Second, we reviewed relevant literature on adoption of improved varieties and quality seed systems in maize and cowpea globally and in Nigeria. Third, we conducted key informant interviews with 25 seed companies; three National Agricultural Seeds Council (NASC) officers; five breeders in Abuja, Kano, and Kaduna states; and four traders and five extension agents in Kaduna and Bauchi states. Fourth, we conducted a household survey with 2,010 maize- and cowpea-farming households in two major maize- and cowpea-producing states with differing historical exposure to seed companies and seed projects: Kaduna (which has a historically high exposure to seed companies and seed projects) and Bauchi (which has a historically low exposure to seed companies and seed projects). Last, we conducted 16 focus group discussions (FDGs) of male and female farmers (and as consumers) in Kaduna and Bauchi. Eight FGDs with male- and female-only participants were conducted per state. With the help of local facilitators, we selected participants on the basis of their household engagement in maize and cowpea production and consumption activities. Attempts were made to include different groups: youth and older adults, poor and rich people, and others. It is noteworthy that the communities are relatively socioculturally homogeneous, with Islam as the predominant religion.

3.1 Study sites and sampling method

The desk review and secondary data analysis are at the national level. Primary data collection focused on northern Nigeria. The concentration of seed companies was in Kano and Kaduna states in northern Nigeria. We interviewed 25 seed companies (large, medium, and small) in those states. We focused on two states to understand adoption of improved varieties and certified seed use among farmers and varietal consumption experiences of farmers as consumers. We chose one state that has many seed companies and historically more exposure to development programs (Kaduna), and one state with historically fewer small-scale seed producers and limited exposure to seed companies (Bauchi). Both states are among the major cowpea- and maize-producing states. In the following paragraphs, we describe their similarities and differences.

Kaduna is a major, fertile agricultural state in Nigeria with adequate rainfall that supports production of arable crops such as maize, cowpea, soybean, sorghum, and rice. It hosts major agricultural R&D institutions, including three National Agricultural Research Institutes (NARIs), consisting of the Institute for Agricultural Research, The National Agricultural Extension and Research Liaison Services, and the National Animal Production Research Institute; the zonal offices of the NASC and Federal Ministry of Agriculture and Food Security; and major seed companies such as Premier Seeds, SeedCo, Value Seeds, Da-Allgreen Seeds, and IAR Seeds. All these institutions ensure trickle-down effects of agricultural innovations and development initiatives in the state.

Kaduna state is divided into four agroecological zones by the Kaduna State Agricultural Development Authority (KADA, formerly known as KADP): Maigana (eight LGAs), Samaru-Kataf (seven LGAs), Birnin Gwari (five LGAs), and Lere (three LGAs). Maigana, the largest zone, includes both Kudan and Soba. Kudan enjoys proximity to the agricultural complex of institutes in Zaria, while Soba is the zonal headquarters of the Maigana Zone of the KADA. Thus, both have relatively high exposure to improved agricultural technologies and practices.

Bauchi state is divided into 20 LGAs, which are grouped into three agricultural zones: Northern Zone, Western Zone, and Central Zone. The main occupation of the majority of the population is farming. Major

crops include sorghum, millet, maize, rice, groundnut, soya bean, cowpea, tomato, onion, and sesame, while dry season major crops include tomato, eggplant, pepper, onion, okra, cabbage, lettuce, watermelon, maize, and date palm. Relative to Kaduna, Bauchi has not been a recipient of many agricultural or development programs or projects.

We used a multistage sampling procedure to select the state, communities, and households included in the household survey. We selected two LGAs per state, totaling a sample of four LGAs: Ganjuwa and Katagum (in Bauchi) and Kudan and Soba (in Kaduna). We used the following criteria for choosing states and LGAs: (1) has safe areas (no or low security issues); (2) are major maize- and cowpea-producing states and LGAs; (3) has certified seed supply (or potential supply), and farmers can access certified seeds if they want to; (4) has logistical feasibility; (5) has a willing local government; (6) includes a network of extension agents, seed companies and traders, or service providers to work on the state LGAs; and (7) has a relatively low adoption of certified seed and improved varieties of maize and cowpea (so that there are huge opportunities to show improvement via interventions).

We used two-stage cluster sampling to obtain a representative sample of this population. First, from the four LGAs, we selected 252 communities that are similar in several important contextual factors: size, socioeconomic and agroclimate conditions, and road and market access. Second, within each community, we then listed households that have planted maize and cowpea in the last three years, from which we randomly selected eight cowpea- and maize-producing households to participate in the study.

3.2. Study context

Security context

Security issues remain a constant threat to many interviewees, though we purposively selected relatively safe LGAs. The two states are quite different. Kaduna is central and has several seed companies, and more farmers mention seed companies as sources of seeds in Kaduna than in Bauchi. Many LGAs in Kaduna have security issues; though we selected two LGAs with fewer security issues, interviewees still mentioned security and theft issues as barriers to farming and adoption of improved varieties and quality seeds. Bauchi is more remote and has limited seed companies (small ones, if any). Seed sources are mostly agricultural development program (ADP) farm centers or other farmers. Again, though we selected two relatively safe LGAs in Bauchi, interviewees mentioned security and theft issues as barriers to farming and adoption of improved varieties and quality seeds.

We selected the four LGAs because they represent major cowpea- and maize-producing areas. Within these LGAs, we randomly selected villages that grow primarily maize and cowpea, although an FGD community said the soil is good for cowpea but not for maize, which could be attributed to the high (nitrogen) fertilizer requirement of maize compared to cowpea. More recently, therefore, the community has been growing cowpea predominantly.

Gendered context

The two states are predominantly communities practicing the Islam religion. In most of the FGD communities, there are strong cultural beliefs and gender norms about women staying in the house and men taking care of livelihoods and generating income. Mobility is a constraint to women in the study sites. Women are generally restricted from going to the farm, attending community/group settings, and going to the market.

Very interesting intrahousehold power dynamics are observed in farming. Women can inherit land from parents and can own land. In the FGDs, all husband and wife (wives) participants indicated that they have their own separate plots, but men (husbands or adult sons) often manage, decide, advise, do almost all physical labor in the female-owned plots, and sell produce in the market. Most women have never seen their own plots; the men in the household take care of them. In the baseline survey, only a few households mentioned any female labor in all stages of farming (from planting and weeding to harvesting and marketing). In addition, women manage only 1 percent of plots, and 3 percent of households mentioned that women have the right to sell the land; only 8 to 18 percent of households have any female family member or female labor involved in any stages of farming, but 40 percent of households indicate some inputs by women in farming decisions, especially households with female-owned plots.

> *"We don't go out. At times, wives go to the farm but not the market. Husbands or our grown-up children go to the market to sell our produce."* Female FGD participant

> *"Yes, some women do engage in production of the two varieties here.... Women have their individual farms..... but who decides on what crops or what variety to grow, it is the male/husband…. He goes to see and inspects the farm. He knows best what the farm needs in terms of harrow, tilling, spraying, fertilizing, cultivation, and harvesting. The husband represents his wife at her farm."* Male FGD participant

However, female farmers decide what to do with the proceeds from the production of maize and cowpea. Decision-making is sometimes done in partnership with the males.

> *"The sales made from the maize harvested is being controlled by the owner, she also decided on what to do with her money. However, she helps out with some of the things at home from her income."* Female FGD participant, Maigana

4. ADOPTION OF IMPROVED VARIETIES AND QUALITY SEEDS

Broadly, four main attributes characterize seed quality: genetic quality, physiological quality, seed health, and physical quality, which are concepts that are hard to measure. In the survey setting, these concepts are even harder to operationalize in ways that farmer respondents can understand and respond to. This complexity and the challenges in measuring the seed quality attributes in the survey setting are the main reasons for varying study results on adoption rates. In this study, we propose a series of indicators to capture the different dimensions of seed quality instead of relying on a commonly used single indicator and binary variable "improved variety." These indicators are based on the following (Table 1 presents the data and results):

1. Farmer-reported use of "improved variety" (binary indicator).[1]
2. Variety name. This is useful in determining the varietal age in farmers' fields, as well as in triangulating data and results. However, the variety name was difficult to collect. Most farmers interviewed referred to seed types or varieties with general descriptions, such as red maize or red cowpea, the name of the person who introduced the variety, or local names. A series of discussions with extension agents, agrodealers, traders, and seed companies were undertaken to link or match farmers' local names and descriptions with the names of officially released varieties. There were some inconsistencies in matching farmer-reported "improved varieties" and farmers' descriptions with the likely equivalent released varieties, but the matching exercise and data triangulation reflect best efforts to identify varieties.
3. Certified seed acquired in the 2022 season of improved varieties.[2]
4. Number of years the seeds are being recycled or reused. Breeders recommend that farmers replace their seed stock and acquire new certified seeds beyond the maximum number of years for replanting seeds of improved varieties before their vigor and quality diminish substantially. For hybrid maize, new seeds have to be acquired every season. For OPV maize, which cross-pollinates, seeds can be planted for up to two seasons. For cowpea, which self-pollinates, seeds can be planted for up to three to five seasons, as advised by the breeders and agronomists interviewed, but the varietal quality and genetic purity of cowpea may not be preserved with poor seed management practices.
5. Farmers' satisfaction with seed quality, measured via a 5-point Likert scale in the survey.

For maize, 41 percent of sample farmers reported using improved varieties, of which 5 percent reported using hybrid maize and the rest reported "local/traditional/landrace." When asked to identify the specific varieties being planted, almost all farmers mentioned local seed type names or descriptions that can likely be matched to "released varieties" (Table 1). The varieties most reported as being planted were likely SAMMAZ 15 (38 percent of households reporting) and SAMMAZ 33/34 (39 percent reporting). Other varieties that less than 1 percent of households reported planting were likely Oba Super 2, 3, 4, and 5; SAMMAZ 27; SAMMAZ 51; Oba Super 13; and SAMMAZ 26 (Table 2). In total, about 94 percent of farmers described their seed types as closely associated with the released varieties; and this figure gives a rough estimate of farmers' awareness and the use of released varieties; however, many farmers recycle these seeds for many years, and for cross-pollinating varieties such as maize, seed vigor and quality

[1] In the survey questionnaire, the following definitions were used and explained to enumerators and respondents: 1 = improved variety (produced by breeders from organizations such as the government or private corporations, officially released through formal channels, and usually designed to improve upon existing seeds, such as by having a higher yield; 2 = hybrid variety (improved and very high yielding but must be replaced every season); and 3 = local/traditional variety (not formally released, and already existed in the village).

[2] In the survey questionnaire, "certified seed" is proxied by asking respondents if they acquired seeds in a sealed bag with label, tag, or code.

diminish substantially, and the original improved variety becomes a different variety after several years of seed recycling. Farmers recycle maize seeds for an average of six years, with some farmers reportedly using their own seeds since they began farming or using seeds from their parents. There were also inconsistencies in farmer-reported use of improved varieties and the matching exercise, based on farmers' descriptions of seed types. To reconcile these discrepancies, we counted the number of sample farmers who reported that they used improved varieties but likely planted a released variety, and we also incorporated other measures of seed quality. When we look at indicators of seed quality, including the number of years the seed has been recycled, we found that 23 percent of producers reported using maize seeds acquired in a sealed bag, and 26 percent acquired seed in a sealed bag and planted seeds for up to two seasons. When we considered and added indicators on farmers' satisfaction, we found that only 18 percent of farmers likely used quality seeds of improved varieties, according to our expanded definition.

For cowpea, 18 percent of cowpea farmers reported using improved varieties. In an attempt to identify the specific cowpea varieties that cowpea farmers planted, we found that 45 percent mentioned local seed type names and descriptions that can likely be matched to released varieties (Table 1). Based on the farmers' description, the cowpea variety most reported as being planted was Kananado, which is likely SAMPEA 9/11 (38 percent of households reporting) (Table 3). Others were likely matched to SAMPEA 18 and SAMPEA 13. These show some degree of diffusion of released varieties; however, farmers recycle the same seeds for many years, which likely diminishes the seed vigor and quality. Farmers recycle cowpea seeds for an average of 8 years, with some farmers reportedly using their own seeds since they began farming or using seeds from their parents. Three to five years is the recommended number of recycling years among cowpea breeders. As with maize, there were also inconsistencies in farmer-reported use of improved cowpea varieties and the matching exercise, based on farmers' descriptions of seed types. Among farmers who mentioned Kananado as their cowpea variety, half called it an "improved" variety, and the other half called it a "local/traditional" variety.

Again, to reconcile these discrepancies, we counted the number of sample farmers who reported that they used improved varieties but likely planted a released variety, and then we incorporated other measures of seed quality. Ten percent of cowpea farmers reported using seed acquired in a sealed bag, and 12 percent of producers reported using seed acquired in a sealed bag and recycling the seed for up to three years (Table 1). When we considered and added indicators on farmers' satisfaction, we found that only 8 percent of cowpea farmers likely used quality seeds of improved varieties.

The rates for Kaduna and Bauchi were surprisingly similar. While Kaduna has more seed companies and historically more seed programs, Bauchi has had its share of seed programs in recent years. For example, Integrated Striga Management in Africa (2011–2014) was implemented in Bauchi but not Kaduna, and the Office Chérifien des Phosphates (2018) included both states. These programs may have increased farmers' exposure to and demand for improved varieties of maize and cowpea seeds in both states.

Table 1. Estimated varietal adoption rates and quality seed use, Bauchi and Kaduna

	Maize			Cowpea		
Indicator	**Bauchi**	**Kaduna**	**Average**	**Bauchi**	**Kaduna**	**Average**
By household						
% of households reporting using improved varieties[a]	38	45	41	23	13	18
% of households reporting using hybrid maize[a]	6	4	5			
% of households reporting local names and descriptions of their seed type that likely match a released variety[b]	91	96	94	48	42	45
% of households acquiring seed in a sealed bag with label, tag, or code (last season)[c]	28	19	23	16	4	10
% of households using seeds acquired in a sealed bag and planted within optimal seed recycling years[d]	29	22	26	18	7	12
% of households reporting satisfaction with the current seed[e]	67	81	74	69	76	73
% of households using seeds acquired in a sealed bag, planted within optimal seed recycling years, and reporting satisfaction with them	21	15	18	12	3	8
By land area						
% of land area with reported improved varieties[a]	37	43	40	21	12	17
% of land area with reported hybrid maize[a]	6	4	5			
% of land area with seed type that likely match a released variety based on the local names and farmers' descriptions[b]	91	96	93	39	37	38
% of land area with seeds acquired in a sealed bag with label, tag, or code (last season)[c]	28	18	23	16	4	10
% of land area with seeds acquired in a sealed bag and planted within optimal seed recycling years[d]	29	22	25	17	7	12
% of land area of households reporting satisfaction with the current seed[e]	67	81	74	69	76	73
% of land area of households using seeds acquired in a sealed bag, planting them within optimal seed recycling years, and reporting satisfaction with them	20	15	17	12	3	7

Source: IFPRI/Binomial household survey on accelerating varietal turnover in Nigeria (2023).

[a] Farmers chose from two options: improved varieties (introduced and modified by breeding program to be high yielding; to be resistant to pest and diseases, drought, or flood; to be early maturing; and to have other traits) versus

local/traditional; for maize, we included a third option: seed that is especially high yielding and cannot be recycled the next season.

[b] Based on farmers' local names or descriptions of the seed type, which were discussed intensively with breeders, extension agents, and traders and matched with their released variety names; unmatched ones were categorized as "local/traditional variety." These give a rough estimate of farmers' awareness and the use of released varieties. Some local names are hard to match; for example, a cowpea variety that farmers call Kananado might be SAMPEA 9, SAMPEA 11, or a local/traditional variety. We matched this local name (Kananado) to SAMPEA 9/11, and these percentages of released variety adoption are on the higher bound for cowpea.

[c] In sealed bag with label, code, or tag in the 2022 cropping season.

[d] Seed of released varieties acquired in a sealed bag within the last three years (2020–2022) for cowpea and within the last two years (2021–2022) for maize OPV; or seed of released varieties that were newly acquired for hybrid maize.

[e] Farmers indicated high or very high satisfaction (using a five-point Likert scale) with seed quality in terms of germination, cleanliness and absence of foreign materials, uniformity of size and color, and overall appearance.

Table 2. Top maize varieties likely planted, and rough estimates of adoption rates and area-weighted varietal age in 2022 rainy season

Farmers' local names or descriptions[a]	Farmers' descriptions[a]	Released variety name (that likely matches farmers' local names and descriptions	Description (based on officially released varieties in cataloge)	Developing institute	Release year	% of households reporting local names that are likely matched to released varieties[a]	% of households using quality seeds of the improved variety[a,b]	Estimated adoption rate of quality seeds of improved varieties (% of land area)	Area-weighted varietal age
Hybrid fari, hybrid ja, Hakorin maciji, Zafa, Masanto, Sasakawa	High yielding; grain size desired; early maturing; resistant to some pests/diseases/weeds; good market demand/price; good taste; flour color desired (white); high flour content; short cooking time; easy processing	SAMMAZ 15	Medium maturing, good seed quality, high yield potential, tolerance to *Striga hermonthica* (6.9 metric tons/hectare [MT/ha])	IITA, Ibadan	2008	38	13	13	14
Boroja, ICT, Yar Aure, Yar gargajiya, Hakorin hajiya, Yar mungo, Yar siriya (in some communities, some of these local names are matched to SAMMAZ 33 or 34)	High yielding; grain size desired; early maturing; resistant to some pests/diseases/weeds; good market demand/price; good taste; flour color desired (white); high flour content; short cooking time; easy processing	SAMMAZ 33/34	SAMMAZ33: extra-early maturing; quality protein maize; good cob and seed size; Striga resistant; drought tolerant; tolerant to maize streak virus disease (3.9 MT/ha) SAMMAZ 34 34: Prolific cob bearing (1-2); leaves stay green after cobs are ready for harvesting, thus, good quality fodder (4.7 MT/ha)	IITA, Ibadan; IAR, Samaru; IITA, Ibadan	2011	39	9	9	11
Buhu banza, Bazawarar mai aure, Bako bakko	High yielding; grain size desired; early maturing; resistant to some pests/diseases/weeds; good market demand/price; good taste; flour color desired (white); high flour content; short cooking time; easy processing	Oba Super 2 (others also call them Oba Super 3, 4, 5)	Oba Super 3: high yield; more adapted to rain forest ecology; more amenable to manual harvesting and excellent husk cover, which makes it less prone to ear rot (7–8 MT/ha) Oba Super 4: more adapted to rain forest ecology; high yield (6–7 MT/ha) Oba Super 5: highly prolific, expressed in good yield; more tolerant to lodging; excellent plant and ear aspect; more suitably adapted to mechanized harvesting; shining, more	IITA, Ibadan	2009	19	2	2	13

Farmers' local names or descriptions[a]	Farmers' descriptions[a]	Released variety name (that likely matches farmers' local names and descriptions	Description (based on officially released varieties in cataloge)	Developing institute	Release year	% of households reporting local names that are likely matched to released varieties[a]	% of households using quality seeds of the improved variety[a,b]	Estimated adoption rate of quality seeds of improved varieties (% of land area)	Area-weighted varietal age
			attractive creamy-white seeds; drought tolerant (8–9 MT/ha)						
Gajera masara, Peageot, Pioneer	High yielding; grain size desired; early maturing; resistant to some pests/diseases/weeds; good market demand/price; good taste; flour color desired (white); high flour content; short cooking time; easy processing	SAMMAZ 27	Drought tolerant; Striga resistant (5.5 MT/ha)	IITA, Ibadan	2009	1	0	0	13
Faran masara	High yielding; grain size desired; early maturing; resistant to some pest/disease/weeds; good market demand/price; good taste; flour color desired (white); high flour content; short cooking time; easy processing	SAMMAZ 51	High grain yield; drought and Striga hermonthica tolerant (8.5 MT/ha)	IITA, Ibadan; IAR, Samaru	2019	1	0	0	3
Premier seed, Mai lalle, Proja, Project, Pure water/yar eka	High yielding; grain size desired; early maturing; resistant to some pest/disease/weeds; good market demand/price; good taste; flour color desired (white); high flour content; short cooking time; easy processing	Oba Super 13	Striga and drought tolerant; high yield (9.7 MT/ha)	IITA, Ibadan; Premier Seed Nig. Ltd.	2016	1	0	0	6
Adoption rate of improved varieties (rough estimate)								**23**	
Area-weighted varietal age of released varieties (rough estimate)									**13**

Source: [a] IFPRI/Binomial household survey (2023) and focus group discussions (2023); [b] series of discussions with extension agents, agrodealers, and breeders to match farmers' local names and descriptions with their likely equivalent released variety.

Table 3. Top cowpea varieties likely planted, and rough estimates of adoption rate and area-weighted varietal age in 2022 rainy season

Farmers' local names or descriptions[a]	Farmers' descriptions[a]	Released variety name that likely matches farmers' local names and descriptions	Description (based on officially released varieties in cataloge)	Developing institute	Release year	% of households reporting local names that are likely matched to released varieties[a]	% of households using quality seeds of the improved variety[a,b]	Estimated adoption rate of quality seeds of improved varieties (% of land area)	Area-weighted varietal age
Kananado Fari, Kananado, Kananado Yar, Farin Kananado, Yar yado	Very high yielding; large grain size; resistant to some pests/diseases/weeds; good market demand/price; good taste; color desired (white)	SAMPEA 9/11*	SAMPEA 9: Dual purpose (good grain and folder yields), acceptable seed quality and good fodder quality SAMPEA 11: Nematode resistance, aphid resistance, good seed quality and field tolerance to major insect/pest (2 MT/ha)	IITA Ibadan, IAR Zaria	2005, 2009	38	4	4	15
Dan Misra	High yielding; early maturing; smaller grain size; resistant to some pests/diseases/weeds; good market demand/price; good taste; color desired (white)	Dan Misra (local variety)				27	2	2	
Nyebbereru	High yielding; resistant to some pests/diseases/weeds; good market demand/price; good taste; color desired (white)	Nyebbereru (local variety)				10	1	1	
Silver wake (local variety)	High yielding; large grain; resistant to some pests/diseases/weeds; good market demand/price; good taste; color desired	Silver wake (local variety)				9	3	3	
Dan arba'in, Dan gombe, Yar arbain	High yielding; resistant to some pests/diseases/weeds; good market demand/price; good taste; color desired	SAMPEA 18	Early maturing, resistant to Alectra and bacterial blight; Striga and drought tolerant (2.5 MT/ha)	IITA Ibadan, IAR Zaria	2018	9	2	2	4
Fari wake	High yielding; early maturity; resistant to some pests/diseases/weeds; good market demand/price; good taste; color desired	Fari wake (local variety)				8	2	2	
Bakin hanci	High yielding; early maturity; smaller grain size; resistant to some pests/diseases/weeds; good market demand/price; good taste; color desired	SAMPEA 13	Appealing color (golden white); good quality even when planted under heavy rainfall (2 MT/ha)	IAR&T, Ibadan	2009	3	1	1	13
Dan Muzakkari	High yielding; resistant to some pests/diseases/weeds; good market demand/price; good taste; color desired	Dan Muzakkari (local variety)				3	0	0	
Adoption of improved								**7**	

Farmers' local names or descriptions[a]	Farmers' descriptions[a]	Released variety name that likely matches farmers' local names and descriptions	Description (based on officially released varieties in cataloge)	Developing institute	Release year	% of households reporting local names that are likely matched to released varieties[a]	% of households using quality seeds of the improved variety[a,b]	Estimated adoption rate of quality seeds of improved varieties (% of land area)	Area-weighted varietal age
varieties (rough estimate)									
Area-weighted varietal age (of released varieties) (rough estimate)									**12**

Source: [a] IFPRI/Binomial household survey (2023) and focus group discussions (2023); [b] series of discussions with extension agents, agrodealers, and breeders to match farmers' local names and descriptions with their likely equivalent released variety.

Note: Most farmers calling their variety "Kananado" may be referring to SAMPEA 9 or SAMPEA 11, but some may be referring to the local variety of Kananado.

Many different estimates of adoption rates of improved maize varieties in Nigeria are available (Table 4a). We compare our findings to those of the LSMS-ISA, which found that, at the national level, 15 percent of maize farmers reported using improved varieties,[3] and 7 percent reported using both certified seeds and improved varieties (Table 4b). For cowpea, 6 percent of farmers reported using improved varieties, and 4 percent reported using both certified seeds and improved varieties. The rates for cowpea are similar to those found in our Bauchi and Kaduna data, although the rates for maize are much lower in the national data than those found in Bauchi and Kaduna.

Other estimates of adoption rates are also available (Table 4). Walker and Alwang (2015) estimated that 97 percent of land area cultivated with maize is planted with improved varieties. Wossen et al. (2019, 2022, 2023), on the basis of DNA fingerprinting of samples collected from farmers' fields across six states in Nigeria, estimated that 67 percent of the maize area (at least) is planted with improved maize varieties, whereas farmers' self-reported data showed an adoption rate of 43 percent from earlier surveys under the DTMA project. However, DNA fingerprinting determines the genetic source and makeup of the seed samples and whether they can be traced to released/bred varieties; otherwise, the seed sample is called local, traditional, landrace, or unknown. While DNA fingerprinting provides information on the genetic purity rate (whether the seed sample has the genetic characteristics of a variety or cultivar), it does not indicate its quality (whether the seed is certified or the other dimensions of seed quality). The percentage of maize seed samples that were classified as improved variety are actually of mixed genetic makeup of different released varieties, with most seed samples having links to SAMMAZ 15 (although with various degrees of genetic proximity).

Wossen et al. (2023), based on certified seed production, estimated that 35 percent of maize area was planted with certified seed in 2020/21, representing a 10-fold growth in certified maize seed production in the last 10 years, from about 3 percent in 2010/11. In our own estimates of certified seed production from 2020 to 2022, we found that certified seed use for maize was 44 percent of land area harvested in 2020/21 (dropping to 28 percent in 2022) and 2 percent for cowpea.

These different figures highlight the notorious challenge in getting consistent adoption rate data and consistent definitions of improved varieties. For maize, the adoption rate estimates range from 3 to 97 percent in the 2010 season and from 7 to 67 percent in later seasons. Nonetheless, consistent with this current study, SAMMAZ 15, released in 2008, has been identified as the most popular variety via DNA fingerprinting, certified seed production, and our household surveys in the roughly 2020–2023 cropping seasons. Our household survey in Bauchi and Kaduna is consistent with the lower bound estimates from the exploration of official certified seed production data in 2020–2022. For cowpea, Walker and Alwang (2015) estimate the adoption rate to be 39 percent of land area cultivated in 2010, which is much higher than the 4 percent adoption rate estimated in the LSMS, our household surveys in Bauchi and Kaduna, and extrapolation from official certified seed production data. Our estimates are close to the extrapolations from certified seed production data.

Continual replacement of old varieties with new and superior varieties with high yield potential and tolerance to multiple stresses can maximize farmers' benefits and adaptation to changing climate (Chivasa et al. 2022; Wossen et al. 2023). Our data show that the varieties in the cowpea and maize plots are old, with area-weighted varietal age in cowpea farms roughly estimated as 12 years and in maize farms, 13

[3] In the LSMS, "improved varieties" and "improved seed" have been used and defined interchangeably across waves. "Improved variety" is defined as "seeds that have some better qualities/traits added to it by a farmer or a plant breeder. They may or may not have been certified. These new traits can be high yielding, drought resistant, or pest resistant…. Traditional/local seeds are those not from improved varieties, typically have been grown in the area for some time and are usually either self-produced or obtained from other farmers or merchants who obtained them locally." The LSMS questionnaire and manual do not include a definition of "certified seed."

years. The most popular cowpea variety is Kananado (likely associated with SAMPEA 9 or SAMPEA 11), released in 2005 or 2009; and the most popular maize variety is SAMMAZ 15, released in 2008. Newer varieties have not caught up in popularity.

These varietal age estimates are overall in line with previous studies although slightly higher than estimates by Wossen et al. (2023): 10 years based on a DNA-based assessment of the area-weighted average age of maize varieties (AWAVA) cultivated in the 2017/18 season and AWAVA values based on the total volume of certified maize seed production in 2020/21. Abate et al. (2017), using household surveys, estimated 13 years as 2013/14 AWAVA. Wossen et al. (2023) emphasized that AWAVA estimates have been declining from 16 years in 2010/11 to 10 years in 2020/21, based on the total volume of certified maize seed production. Our estimates are close to other estimates and consistent with this general trend over time.

Table 4a. Adoption rate of improved varieties of maize and cowpea

Author	Crop	Adoption rate	Definition of improved variety	Season/ Year	Sampling	Popular varieties
Takeshima et al. (2022a), based on LSMS-ISA, four waves	Maize	15% of rural households using improved seeds; 7% using certified seed of improved variety	Survey questions used: "Did you grow improved maize varieties during the last agricultural season?" and "Did you use certified seeds?"	2010/11, 2012/13, 2105/16, 2018/19	Nationally representative	
Wossen et al. (2023)	Maize	67% of maize area, based on DNA-fingerprinting	DNA fingerprinting determines the genetic source or makeup and can tell if seed sample has some gene lines of the released/bred/improved varieties; otherwise, seed sample is called local/landrace/unknown.	2018 DNA-fingerprinting; various years of certified seed production data		Sammaz 15
Oyetunde-Usman et al. (2021)	Mainly maize	14% of sample rural households	Adoption of improved seeds (0,1); no definition given.	2015 Nigeria General Household Survey	Nationally representative	
Abdoulaye, Wossen, and Awotide (2018)	Maize	57% of farmer households using improved maize varieties that season	Improved variety (0,1) based on survey question: "Did you grow improved maize varieties during the last agricultural season?"	2014–2015 study survey (cross-sectional data)	18 states	Oba Super 9, Ba Hausa, EVDT 99, 3DT Com, Yar Masara, Sammaz 37
Abate et al. (2017)	Maize	26% of land area cultivated (12% hybrid maize) (varietal age: 12.6 years, compared to 14.9 years in SSA)	Adoption of improved varieties as a percentage of land area cultivated; improved varieties defined as either hybrid = freshly purchased hybrid seed or improved OPV = seed that has not been recycled for more than three seasons; versus local (or farmers' or traditional) cultivars = landraces, recycled hybrids, OPVs recycled more than three seasons, and/or those for which no information is available	2013/14 cropping season	Based on adoption monitoring household surveys carried out in 13 countries across SSA under DTMA; sample sizes for the surveys ranged from 397 to 947 farm households per country	Oba Super 9, Ba Hausa, EVDT 99, 3DT Com, Yar Masara
Walker and Alwang (2015)	Maize	97%	Released variety (including escapes, participatory selection trials, and breeding outputs in countries without formal release process); cutoff year (e.g., 1960 or 1965 for rice); and included maximum seed replacement, only when there are survey data	2010	Mainly from expert panel; survey data for a few countries/crops	

Author	Crop	Adoption rate	Definition of improved variety	Season/ Year	Sampling	Popular varieties
Walker and Alwang (2015)	Cowpea	39%	Released variety (including escapes, participatory selection trials, and breeding outputs in countries without formal release process); cutoff year (e.g., 1960 or 1965 for rice); and included maximum seed replacement, only when there are survey data	2010	Mainly from expert panel; survey data for few countries/crops	

Source: Various studies.
Note: DTMA = Drought Tolerant Maize for Africa project; OPV = open-pollinated variety; SSA = Sub-Saharan Africa.

Table 4b. Seed use, based on nationally representative data from LSMS-ISA

Variable	Crop	Average (all 4 rounds)	Median (all 4 rounds)
Yield (MT/ha)	Maize	2.063	1.172
	Cowpea	1.304	0.700
Using improved seed (yes = 1)[a]	Maize	0.153	0.000
	Cowpea	0.058	0.000
Using certified seeds (yes = 1)[a, b]	Maize	0.072	0.000
	Cowpea	0.035	0.000

Source: Adapted from Takeshima et al. (2022a), based on NBS and World Bank (2019).
[a] Only reported in wave 3 (2015) and wave 4 (2018).
[b] Use of certified seeds = 1 if the respondent indicated so, regardless of whether the respondent called them "improved seeds" or "other seeds (traditional, local)."
[b] Use of certified seeds = 1 if the respondent indicated so, and only if the respondent called them "improved seeds," and this is the most restrictive definition.
Note: LMSA-ISA = Living Standards Measurement Study – Integrated Survey on Agriculture; MT/ha = metric tons per hectare.

5. SOURCES OF SEED AND INFORMATION

The most common methods for getting information on new varieties were other farmers, friends or relatives, and agrodealers or traders (Table 5). A few surveyed households mentioned seed companies, and a few FGD participants mentioned an ADP farm center or extension agents.

Similarly, the most common methods for getting new seed varieties were agrodealers/traders, other farmers, and friends or relatives. A few surveyed households mentioned seed companies, and a few FGD participants mentioned an ADP farm center or extension agents as the source of new seed. There was a high rate of seed recycling; the majority of farmers reported getting seeds and information about seeds from their own seed recycling. Seeds were often purchased in sealed polythene bags or in big sacks.

Only a few women were involved in maize and cowpea farming or have their own plots. For those women, they often got information on a new variety or on seed of a new variety from a husband or male relative. Some women who can travel got information on a new variety or on seed of a new variety from an ADP farm center or agrodealer.

In terms of cooking or preparing harvested crops, the most common source of learning about new dishes, for both women and men, was radio programs. The second source was friends or relatives, and the third was television programs, according to FGDs. There was limited phone ownership and internet use in the study site.

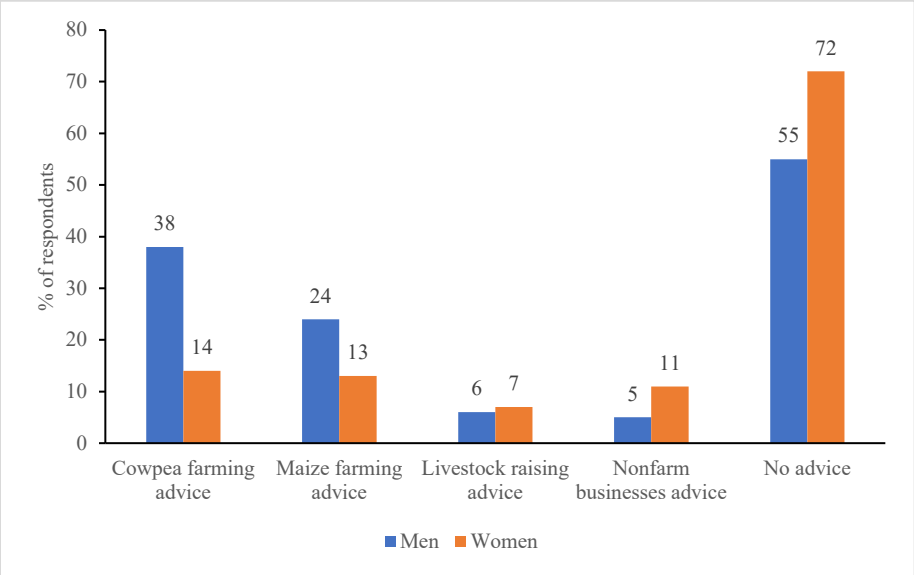
Table 5. Sources of information and seed (% of sample households), Bauchi and Kaduna

	Maize		Cowpea	
Source	**Source of information about variety**	**Source of seed**	**Source of information about variety**	**Source of seed**
Friends/relatives	55	29	65	24
Own saved seeds	16	60	16	61
Agrodealers/traders	30	15	28	18
Seed companies	9	3	3	1
Government/NGO project (including ADP farm center)	3	1	1	0
Village head/traditional authority	1	1	2	1
Open market	1	1	1	1

Source: IFPRI/Binomial household survey on accelerating varietal turnover in Nigeria (2023).
Note: NGO = nongovernmental organization; ADP=agricultural development program.

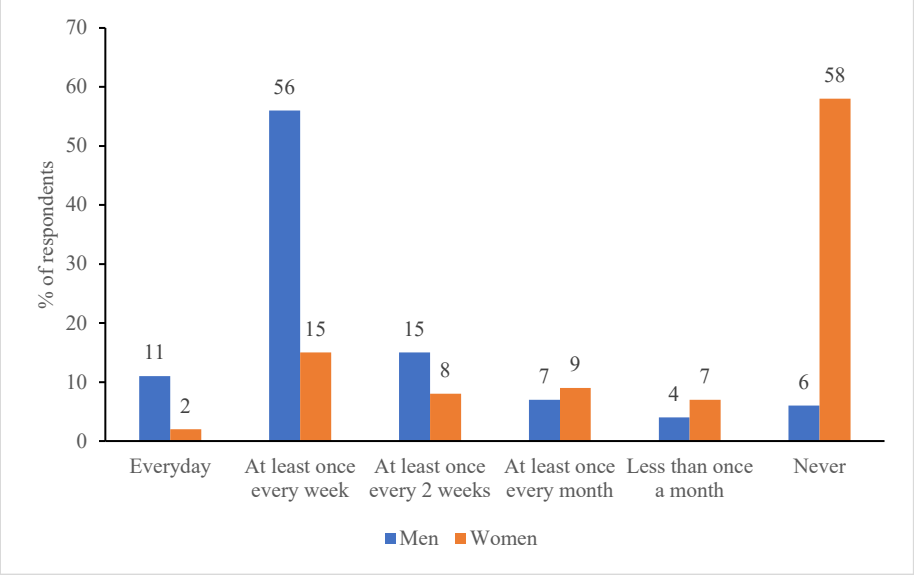
Access to extension services was limited. Only 38 percent of male respondents reported having access to extension services on cowpea and 24 percent of male respondents on maize farming (Figure 3). The majority of female respondents (72 percent) did not have access to any extension services. Another way to get information on improved varieties is going to the market to interact with agrodealers and other farmers, with 67 percent of men reporting going to the market at least once per week; however, market access remained a restriction for women, with the majority (58 percent) of women reportedly never having gone to the market (Figure 4).

Figure 3. Access to extension services, Bauchi and Kaduna



Source: IFPRI/Binomial household survey on accelerating varietal turnover in Nigeria (2023).

Figure 4. Frequency of going to the market, Bauchi and Kaduna



Source: IFPRI/Binomial household survey on accelerating varietal turnover in Nigeria (2023).

6. PRODUCTION CHALLENGES AND DESIRABLE TRAITS OF VARIETIES

The most reported challenges in maize farming were poor soil; costly inputs, especially fertilizer; climate change such as increased drought and flooding; pests and diseases; seed issues (adulteration and low germination/productivity); and lack of extension services (Table 6a). The most reported challenges in cowpea farming were similar: pests and diseases; costly inputs, especially fertilizer; lack of capital; climate change such as increased drought and flooding; poor soil; and seed issues (not fertile, waterlogged) (Table 6b). Challenges in cowpea and maize farming were similar, as were preferred traits of maize and cowpea varieties (Figure 5a and 5b). The reported challenges and related traits were similar across communities where we conducted the FGDs and across female and male participants.

Table 6a. Maize production and consumption issues and related varietal trait preferences

Production challenges	Desirable production traits	Consumption/cooking issues	Desirable consumption traits
High cost of inputs (fertilizer and herbicides)	High yield	Difficulty processing into flour	Variety with good-quality flour
Pest and disease infestation	Big and multiple cobs	Short shelf-life for maize flour after cooking	Good taste and smooth when cooked
Poor soil	Early maturing	Long cooking duration	Easy to process
Climate change, such as more drought and flooding	Pest and disease resistant	Wet flour that becomes easily spoiled	Long shelf-life
Seed issues (adulteration, low germination)	Drought tolerant	Insufficient flour in some varieties	Short cooking duration
Inadequate extension services	Requires less fertilizer	White maize that is not palatable	Sticky grain (mentioned in a few FGDs)
Use of traditional farming system		Not sticky grain (mentioned in a few FGDs)	

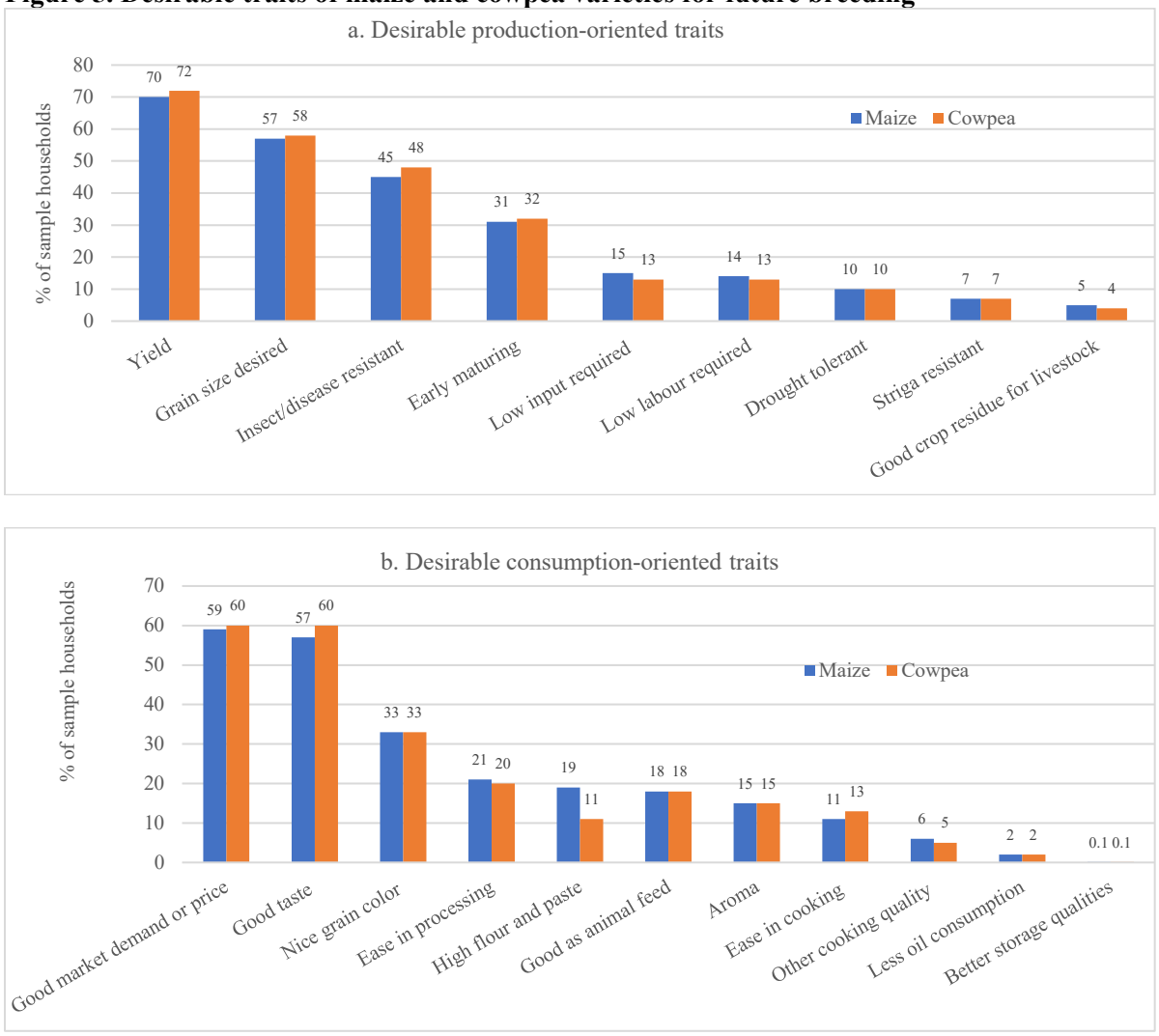
Source: IFPRI focus group discussions, 2023.

Table 6b. Cowpea production and consumption issues and related varietal trait preferences

Production challenges	Desirable production traits	Consumption/cooking issues	Desirable consumption traits
Severe pest and disease infestation	High yield	Difficulty processing and cooking	Easy to process
Storage problems	Early maturing	Low shelf-life after cooking	Good taste and palatable
Poor market price	Pest and insect resistant	Storage problems	Free from weevil infestation
High fertilizer costs	Big size seed	Constipation	Short cooking duration
Climate change, such as more drought and flooding	Good storage quality	Long cooking duration	Varieties free from abdominal discomfort
Poor soil (not fertile, water-logged)	Viable seed (mentioned in a few FGDs)	Bad smell from cowpea residue	Longer shelf-life
Lack of certified and viable seeds			Good storage quality

Source: IFPRI focus group discussions, 2023.

Figure 5. Desirable traits of maize and cowpea varieties for future breeding



Source: IFPRI/Binomial household survey on accelerating varietal turnover in Nigeria (2023).

Yield was by far the most important trait of maize and cowpea variety valued by farmers (Figure 5). The color and grain size of cowpea and maize were also major traits that producers and consumers looked for. Large grains were mainly preferred (although a few farmers preferred small grains for some specific dishes). In our baseline survey and FGDs, we asked female and male famers the color of cowpea they planted and preferred. White cowpea and maize were mainly preferred, although some farmers preferred brown cowpea or yellow/orange/red maize for some dishes and in industrial use (poultry feed). Yellow/orange/red maize is used for green maize, roasting, boiled corn, *tuwo, dambu*, and popcorn. Brown cowpea is good when cooked whole, as in jollof, spaghetti, or bean porridge; white cowpea is usually preferred for dishes that require flour or ground cowpea.

For both cowpea and maize, farmers also valued pest or disease resistance and early maturity. Some FGD participants also mentioned heavy grain, big cobs, and multiple cobs, still related to good yield. Good market acceptance, and market price were other major traits preferred along with good taste (that is, often sweet maize or cowpea was preferred).

Other important production-oriented traits of maize and cowpea varieties mentioned by some farmers were low input and labor requirement, drought tolerance, Striga resistance, and good crop residue for livestock. Other consumption-oriented traits mentioned by some farmers were ease in processing or milling, high flour output or paste, good use as animal feed, aroma, cooking ease (for example, less cooking time), other cooking qualities (for example, smooth texture, consistency), less oil consumption, less chaff or bran, and better storage qualities. For cowpea, some FGD participants mentioned long pod.

7. BARRIERS TO ADOPTION

Next, we identify various factors hindering the adoption of recently released crop varieties. These barriers encompass both supply and demand aspects; contextual versus seed-system-specific challenges; economic, informational, cultural/normative, or behavioral dimensions; and capacity and incentive problems (Table 7).

Two main hurdles emerged as barriers to the adoption of improved varieties. First, seeds were scarce, particularly breeder and foundation seeds. To address this limitation, there is a need for increased funding and improved capacity for early-generation seed production and management. Second, there was a deficiency in promoting and exposing farmers to these new varieties. Both the public and private sectors should invest more in promoting and testing these varieties among farmers.

It is also essential to scrutinize the breeding and characteristics of these newer improved varieties. Many of them do not consistently outperform older bred varieties in the field.

7.1. Contextual factors

Contextual factors that act as enablers or disablers for expanded seed production and increased adoption of improved varieties were plentiful (Table 7). Poor soil conditions and limited fertile land discouraged the expansion of seed production by seed companies and small-scale seed producers. Poor soil conditions and the related high cost of fertilizer were the contextual factors discouraging adoption of improved varieties by grain farmers. The high cost of diesel, irrigation, and transportation were major hurdles to expanding seed production. Security and theft issues were reported by both seed producers and grain farmers as factors that discouraged expansion of seed production and adoption of improved varieties.

> *"Initially when we started the production of certified seed of maize in 2013, we made profits but subsequently we experienced loss, and this is one of the reasons why we stopped. You can imagine losing over half of what you invested because of thieves and hikes in the price of diesel."* Seed company

> "*The biggest constraint to maize farming is fertilizer…. We also suffer from stem borers and other maggots inside soil in our fields…. There are other forms of disease which cause the root of maize plant to dry and die off."* Male FGD participants, Maigana

Table 7. Barriers to adoption

Barrier	Type of challenge/ problem	Supply- or demand-side factor	Affected group(s)	Illustrations of impact
Poor soil quality and fertility (big issue in the north)	Contextual, capacity	Supply and demand	Seed companies, producers (women, men)	Results in limited fertile land to expand seed production; low yield of seed production, which discourages continued seed production; low productivity among producers, which discourages IV adoption among producers; and increased demand for nutrient-efficient varieties (those that require less fertilizer)
High fertilizer costs	Contextual, capacity	Demand	Seed companies, producers (women, men)	Results in low fertilizer use, suboptimal management practice, low IV productivity, and low IV adoption overall but increased demand for nutrient-efficient varieties (those that require less fertilizer)
Security issues/theft	Contextual, incentive	Supply and demand	Seed companies, agrodealers, producers (women and men)	Results in limited areas to expand seed production; constrains seed business operations; results in low adoption of red maize IV and brown maize IV, which are more prone to theft
Transportation, diesel, and irrigation costs	Contextual, capacity	Supply	Seed companies	Results in limited expansion of seed production
Drought, flood, and rainfall fluctuations	Contextual, capacity	Supply and demand	Seed companies, producers	Results in low productivity and low IV adoption overall but increased demand for tolerant or resistant varieties
Poor knowledge and poor management practices lead to low productivity, poor performance of seed; farmers associate poor yield with seed performance	Contextual, behavioral, incentive	Supply and demand	Producers (women, men)	Results in seed recycling, low adoption of IV and certified seeds
Resistance to change (~90% of farmers)—risk aversion and/or negative experience, but this is improving over time with more exposure and experience with IVs and certified seeds	Behavioral, incentive	Demand	Producers (women and men)	Results in low adoption of IVs; no matter what, many farmers prefer the old/older varieties (they need a lot of convincing to change)
People prefer “white” cowpea or maize in their food and in the market	Behavioral, informational, incentive	Demand	Producers (women, men)	Dislike for brown cowpea or orange/red/yellow maize results in low adoption of the high-yielding and nutritious colored new varieties (e.g., biofortified ones)

Barrier	Type of challenge/ problem	Supply- or demand-side factor	Affected group(s)	Illustrations of impact
Search and transaction costs for seeds, IVs	Behavioral, contextual, incentive, capacity	Demand	Producers (mentioned especially among women)	Uses local seeds
Trust in agrodealer/ADP farm center leading to not finding out about and seeking new IVs	Behavioral, capacity, incentive	Demand	Producers (mentioned especially among women)	Slows the process of adoption
Restriction in group/community gatherings	Cultural, capacity	Demand	Women	Limits interaction and learning, access to information and services through groups; results in lower IV adoption
Lack of information on IVs, especially among women, as they are not considered farmers (women get advice and IV samples from husband or other male relatives)	Cultural, informational, capacity	Supply	Producers (mentioned especially among women)	Limits discussion, cooperation, and joint search of and experimentation with new varieties, which slows the adoption process

Source: Authors' compilation from focus group discussions with farmers and in-depth interviews with seed actors.
Note: ADP = agricultural development program; IVs = improved varieties.

Droughts, floods, and other extreme and unpredictable weather events are also major disablers of adoption of improved varieties that are new and untested, and therefore risky on the part of producers. However, there is also stronger demand for new varieties that are tolerant or resistant to these weather events. Adoption can therefore be accelerated if these traits are incorporated into popular varieties (those already tested by farmers with traits they like), for example, Kananado (SAMPEA 9) for cowpea and SAMMAZ 15 for maize.

There are several policies, regulations, and programs in the seed system. The new National Seed Policy, launched in 2022, lays down the policy direction and comprehensive strategy for the seed sector. Poor implemenand and enforcement of policies and regulations, however, can be major disablers of effective seed systems and of farmers' adoption of improved varieties. While government policies can play a vital role in production, some can be harmful and create dependence. Some can be disruptive if not properly implemented, funded, and enforced.

> *"Actually, government policies mostly affected the seed companies. Most times, the government does things without consulting the right stakeholders. When they came in with this Anchor Borrower programme, it spoilt everybody's market. ... when they set up the Anchor Borrower programme, the NASC also made a mistake as somebody who doesn't even have an office, doesn't have any facilities, they just register them as a seed company. People just started buying grains in the market and packaging them as seeds and that made farmers lose confidence in our seeds."* Another seed company

> *"They said we have 350 seed companies in the country, but do they (NASC) have 350 seed inspectors? They are generally short of seed inspectors. Those people that didn't invest in the business but got sponsored by the Anchor Borrower/Central Bank will just end up operating as seed companies and therefore sell at a lower price, hence, killing our market. Another thing that*

killed our business are these people that are taking the seeds from those who benefitted from the Anchor Borrowers Programme as they sell the seeds to the market at a giveaway price. For example, if I sell my seed at 500 naira per kg, they may sell theirs at 150 naira per kg. Now tell me, who will come and buy mine? I can categorically tell you that almost all the seed companies in the country are affected." Seed company

"Lack of continuity in extension and agricultural programs." Male FGD, Maigana

7.2. Breeding and breeder seed production

According to the National Seed Policy 2022, public and private sectors can conduct breeding and produce breeder seeds. The private sector's breeding and breed seed production focus on hybrid seeds. Public research institutes have breeding programs for maize, cowpea, and other crops. Most interviewees indicated a very low budget in government breeding and research institutes and for maintaining breeder seeds. The findings are also consistent with the observations expressed by seed companies about the shortage of basic seeds in Nigeria (Waithaka et al. 2019).

"Breeders are doing their best, but there is such lack of funding." Seed company

"One problem we also face when we go to these institutes is that they do not have some of these varieties when we need them." Seed company

"Most times they are not available and even when you get them, they are insufficient." Seed company

Some varieties failed in demonstration plots or had quality issues.

"Most of their varieties are good, except for some that failed on demo sites like I mentioned." Seed company

"There was a time we had a problem with FARO—66 that we bought from a research institute, they had to recall that back after we reported, and they paid us compensation." Producer of foundation seed

Often, equipment and labs to test for quality were not available.

"I am one of the breeders in the sunflower unit and we don't even have a lab and sunflower needs quality oil and if you don't even know how to taste the oil in our varieties, how can you release sun flowers? This is the major challenge we are facing as a breeding institute." Maize breeder

Older bred varieties, such as the SAMMAZ 15 and SAMPEA 9/11, are still very popular among farmers, and the newer varieties have not caught up in popularity. We investigated whether this is due to the varieties themselves (they are not comprehensively better than the older bred varieties), lack of seeds (farmers are aware of the newer varieties and would like to plant them, but there are no seeds available), or lack of promotion and farmers' lack of awareness of the seeds. The available evidence points to all three reasons.

First, we asked farmers to name varieties they are aware of and whether there are varieties they know about and would like to plant, but they could not get access to the seeds. Responses were consistent; all respondents did not report any variety they knew about and would want to plant but they did not have access

to the seeds. We also asked whether there are recent farm demonstrations, seed trial packs, or extension services on new varieties in the communities. All these investigations consistently point to the absence of any promotion or information campaign, farm demonstration, or seed trail packs of newer varieties. It is therefore not a surprise that almost none of the respondents were aware of or had planted the newer varieties. A recent experiment that promoted seed mini-packs of newer varieties (SAMMAZ 51, SAMMAZ 52, SAMPEA 19, and FUMPEA 3) shows zero knowledge and exposure of these varieties at baseline and farmers wanting and demanding the seeds after trying the seed mini-pack (Ragasa et al. 2024). This reveals the limited exposure that farmers have, and how exposure can affect farmers' demand of improved varieties.

Second, we looked at the certified seed production data, which show that certified seed production is still mostly of older bred varieties, particularly maize SAMMAZ 15 and cowpea SAMPEA 9/11. Third, we investigated why there is limited certified seed production of newer varieties—is it due to performance of the newer varieties or lack of further testing and field demonstrations and therefore lack of demand and interest from farmers, or is it because few seed companies can supply breeder, foundation, and certified seeds of these newer varieties?

> *"It takes some time for the system to get to breeder seed production and then to foundation seed, and finally to certified seed production. With few seed companies and weak seed systems, this commercialization process usually takes time. That is why we see the older varieties, like SAMMAZ15, still popular as it takes time for a new variety to get into certified seed production and additional few years are also needed for farmers to try out and experiment before there is wide adoption of the new variety."* Breeder

> *"…but there were exceptionally superior newer varieties in the past where there was a lot of demand from seed companies and farmers, so they get prioritized and fast-tracked in terms of commercialization and promotion."* Seed expert

These available evidence point to the importance of three factors that complement each other: (1) having newer varieties that are superior or convincingly better in many dimensions than popular varieties (demand side; farmers' incentive to adopt); (2) a strong seed system that makes quality seed available to farmers (supply side; seed accessibility and affordability); and (3) promotion, awareness, and experimentation among farmers (demand side: farmers' knowledge, incentive, and capacity).

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7.3. Foundation seed production

The National Seed Policy permits public and private sector involvement in the production of breeder and foundation seeds. Five public institutes have NASC licenses to produce breeder and foundation seeds, and four private institutes have licenses to produce foundation seeds—and they all work on maize foundation seeds. IAR and IAR&T are producing breeder and foundation seeds for maize and cowpea. There are issues of supply and quality of foundation seeds, according to some seed companies.

> *"Sometimes when you go for foundation seeds you just pray that you dabble on the right one. Like I said before you might not even get the right one. At times when you pass through the NASC to get these seeds, you will have to pay some tokens which ordinarily shouldn't be part of the process. So, there is insufficient seed quantity."* Seed company

> *"The foundation seed producers are new, and many seed companies are not yet aware of them. There is currently a lack of capacity among many seed companies to source, use, store, and manage foundation seeds. We need to strengthen their capacity, and we need a stronger coordination and linkages among the different seed actors."* Seed specialist

7.4. Certified seed production

About 300 certified seed producers are NASC registered and listed on the seed portal website. However, most seed actors claimed that many of those seed producers are inactive.

> *"There is lack of capacity among seed producers to produce good quality certified seeds."* Seed specialist.

Many seed actors noted the negative effect of artificial incentives via subsidies that made many seed producers register and apply for these subsidies. Without strong implementation, regulation, and coordination, these types of subsidies often do not work.

> *"Many of them did not have the capacity and eventually did not survive and the subsidies just distorted the market and mudded the trust and confidence of farmers on seed companies in general."* Seed company

There seems to be a large reputational risk and externalities in the seed sector: Farmers operate on trust and experience. Once farmers have a negative experience with a seed, they think all the seeds are bad and will never try them again. The importance of trust and experience is magnified by the fact that the adulteration of seeds sold in the markets is still pervasive in SSA (e.g., Bold et al. 2017), often leading to reduced willingness to pay for seeds from the market (Gharib et al. 2021).

There is an existing paradox in seed demand: Some companies have lower supply than demand, whereas other smaller companies have limited demand and are laying off staff due to low sales. This may just reflect the companies' performance and service quality and the communities they operate in.

> *"Sometimes our certified seeds are not enough so we end up sourcing for seeds from other seed companies to meet up with our demands."* Seed company

7.5. Farmers' demand, capacity, and incentives

The inadequate demand for improved varieties and certified seeds is largely due to lack of exposure. We observed limited knowledge on varieties and demand for specific improved varieties, especially among women.

> "*Once we are at the ADP farm center, we assume everything there is a good product. So, we don't pay attention to any writings on containers. We trust they will give us good products and not bad ones because they were put there to assist farmers do what is right."* Female FGD participant

Poor knowledge and poor management practices contribute to low productivity and therefore to poor seed performance. This is consistent with the findings in Nigeria that farmer education is critical for enhancing the returns to improved cowpea varieties (Alene and Manyong 2007). Farmers associate poor yield with poor seed performance. When trying out new varieties, farmers often attribute poor performance to seed performance without considering management practices, which creates negative experiences, impressions, and evaluations of new varieties and dampens the farmer's demand for quality seed of improved varieties.

A related issue is farmers' resistance to change, perhaps from negative experience or plain risk aversion. FGD participants thought that most farmers in their communities are resistant to change and that it will take much effort to convince them to change.

> *"I bought mine from my brother. I have been planting this brand, Acre brand for the past 15 years or so. It is the only brand I plant."* Male FGD participant

> *"I have been planting Kananado. I saw my parents planting it and I just kept on planting it. I have not experienced something better than it."* Male FGD participant

Also related is the search and transaction cost of searching for and experimenting with new seeds. Producers, especially women, simply just do not have the time, resources, and incentives to do so.

> *"We want uncomplicated—we sell seeds, we buy seeds from other farmers.... Most of us prefer planting local seed because it is easy to come by and cheap."* Female FGD participant

We need to promote these new varieties. Many interviewees also highlighted that, with exposure, things can change. Without promotion and samples for farmers to try, new varieties never get tested and adopted in farmers' fields.

> *"We hear from radio sometimes that there is one better than Silver, but it was not brought to us… so we do not have experience about it."* Female FGD participant

Two themes were investigated in the FGDs. First, lack of information and exposure of new varieties is the major issue preventing adoption of these new improved varieties. Second, we asked farmers whether lack of funds for seeds or high seed cost was a barrier in adopting newer improved varieties. When we explained that seed costs just US$11–15 per hectare and is about 2 to 5 percent of the total value of production, participants then said that it is not seed cost but fertilizer cost that is a problem. They added that, if the seed is tested and proven to be of good quality, they buy it, again confirming that the problem is lack of exposure and of being able to show seed to farmers and have them test and prove its quality. The fertilizer cost issue means that production and seed performance will most likely be low without adequate fertilizer, given the poor soil conditions. Addressing this issue of low soil fertility seems to be a priority action.

8. STRATEGIES TO ACCELERATE VARIETAL TURNOVER

Three major themes emerged from FGDs and in-depth interviews as drivers of adoption of newer improved varieties: (1) very good varieties that are tested and proven to be better than older varieties, (2) adequate supply of quality seeds from breeder seeds to certified seeds, and (3) strong promotion of these varieties and adequate exposure and testing among farmers. All seed companies were aggressively promoting and marketing, but only a few were reaching all farming communities, especially in remote areas. Below we elaborate on the strategies needed to help accelerate varietal turnover and quality seed use in Nigeria.

8.1. Contextual factors

Beyond seeds, several contextual factors hindered farmers' and seed actors' capacity and incentive to expand production and adopt improved varieties. Security issues, poor soil conditions, and high costs of fertilizer, transportation, irrigation, and diesel were some of the major barriers in the seed system that must be addressed. Fertilizer subsidy, integrated soil fertility management, and breeding for nutrient-efficient and low fertilizer–demanding varieties were some of the options reported by farmers and seed companies:

> *"Farmers also need support to boost their production. Today fertilizers are very expensive. The government should look into producing these agro chemicals or selling them at a subsidized rate. Lots of farmers would rather save their seeds just to buy fertilizer because of how expensive these inputs have become in turn end up harvesting low yield."* Seed company, with similar responses from many seed companies and FGD participants

Some seed companies were in favor of more input subsidies.

> "*Government intervention by sharing of seeds freely to the farmers was a very good strategy adopted to promote the adoption of the hybrid maize varieties. ... Government policies actually play a vital role in production. Take for example the Growth Enhancement Support (GES) programme, maize association programme and the anchor borrowers. These are schemes created to assist the farmers. This year, we released 300 metric tons of hybrid maize but only 180 metric tons were bought due to the high cost of fertilizer and insecurity. Government should look into assisting the farmers with subsidies so as to ease their cost of production."* Seed companies

Others were more in favor of investing and improving the system so that markets are more efficient; input, transportation, and transaction costs are reduced; and the quality of inputs and services are improved. They recommended supporting breeding institutes, seed companies, and agrodealers so that they have technical and financial capacity to produce, source, and manage quality seeds. They also recommended that the government coordinate and regulate these actors to ensure that only quality seeds flow into the system.

8.2. Breeding and breeder seed production

More funding is required for research and breeding.

> "*I would love to see a synergy between the public and the public institutions. If we keep saying the public institutions should be funded by the government, to be honest we won't get the funding required but if these seed companies can be honest with themselves, they make more money from these seeds than we. For example, they have a marketing strategy as far as I am concerned. They*

have local outreaches with the local farmers, so when you look at it, you'll realize their marketing department is very strong; but who does the work? We (breeders) do the work. Once we release, we enter into an agreement with them, and they go ahead to make money from our seeds without even giving us any royalties whatsoever. When you travel abroad, there is what is called TRUST. There is a maize trust, wheat trust, cowpea trust and etc. and these organizations are cooperatives where farmers, breeders, marketers and other commodity traders belong to and there is a pool, we are getting services, when we get all these supports from the breeding institutes, let's give back to them. A very little percentage say 1% of our turnover in a year should be given back to research." Breeder

Increasing funding for breeding, particularly for crops like maize and cowpea, is crucial. Recent studies highlight the vital role of adaptive research conducted by the National Agricultural Research System, especially in SSA, which includes Nigeria. The varied environmental conditions in SSA, as discussed in the literature, create differences in the effectiveness of specific crop varieties, such as hybrid maize (Suri 2011). The research suggests that improving the capacity for plant breeding is essential in SSA, where there is a shortage of breeders compared to Asia or Latin America (Maredia et al. 2000).

Nigeria, being the SSA country with the largest agricultural area, experiences significant diversity in agroecological conditions. To boost productivity, it is important to establish more decentralized plant breeding systems for crops like maize and cowpea (Takeshima 2019). Recent studies indicate that increasing public spending on agriculture in Nigeria can notably enhance agricultural productivity (Takeshima et al. 2022b). One crucial step in achieving this productivity is to expand local adaptive R&D capacity.

Similarly, evidence from other SSA countries suggests that when local seed companies invest more in adaptive breeding, it leads to increased productivity (Bird et al. 2022). This underscores the importance of policies that encourage private sector investment in breeding better varieties, including hybrid maize.

There could also be more focus on commercialization.

"More focus should be shared on commercialization. There are more products on the ground but not commercialized. Breeding should be market led and not research led only." Seed company

8.3. Foundation seed production

More firms can be encouraged to produce foundation seeds. The capacity among many seed companies to source, use, store, and manage foundation seeds needs to be strengthened. This requires stronger coordination and linkages among the different seed actors, which will require a stronger government role.

8.4. Certified seed production

Seed companies promote heavily, but there are only a few large seed companies, and they focus on a few states. Many states and localities are not covered by promotion, so farmers are not aware of new varieties. The government and its partners will need to strengthen extension services on good agricultural practices, including improved variety use and seed management.

"Government policies around extension services are not enough. Farmers at times are taught something but do not have the guide to carry it through due to the shortage of community extension

services and seed companies cannot do all these for them. You know that if they do not adhere to the agronomical practices, even if they use the improved seed varieties, they may end up not harvesting the rightful yield." Seed Company

The government should also strengthen seed system coordination and support good seed companies. More human resources and sustained funding are needed to strengthen NASC's regulatory and coordinating function. Private-sector or third-party certification should be considered.

"The staff of the NASC, their manpower is not enough. You can imagine us having many fields, but we are only assigned just one seed inspector." Seed company

"One policy that I think should be investigated is certification … if there is a way that it can be privatized because of inadequate manpower. Look, for example, at our production capacity with only one certification officer from NASC. To be very honest, that is not enough. It is giving room for compromise in the sense that a certification officer can be servicing two companies and to be very honest, there is a huge gap and shortage of manpower. There should be a policy enacted by NASC for seed companies that every seed company has its own seed certification officers just like we have seven working in our organization. In fact, no seed company should operate without an internal seed inspector. If this means NASC training the staff from these companies let this be a foundation and must for all seed companies as the NASC inspectors cannot do this all on their own. A database or cloud where the evidence of the routine work done by the NASC trained seed companies inspectors can be shared monthly and those who do not meet with their work can be fined. Also, NASC should consider giving room for private companies to be established that would help in the supervision of these seed companies so as to minimize the huge work NASC is doing presently." Seed company

Seed producers (or prospective seed producers) should be given exposure, training, and skills development. Community seed schemes, farmers' groups, and cooperatives involved in seed production are good examples of budding entrepreneurs who have interest and some experience but need capacity strengthening and technical assistance (see Takeshima et al. 2024). As stated in the National Seed Policy, these groups should be supported to strengthen their capacity to gradually transition and be registered as certified seed producers.

"Our company was established in May 2002. You know I am an agriculturist by training, and I have a lot of interest in seed. Even when I was with the government, I was on a seed multiplication scheme. That was how I developed an interest in seed production so when I retired, I moved straight to a seed company in 1984, and I served in different positions. I established a seed company in 1996; …. changed the name in 2000 though it became an official company in May 2022. So, all the while, I have had this interest of starting my own seed company meet up with the demand for good and improved varieties in the society at large." Seed company

Equipment support from the government is also needed.

"We have a processing unit that was gotten from the federal government which was given to us at a discount of 30%. There is a generator, there is a processing machine, sealing machines, scales for measuring, two tractors, one combine harvester, three maize threshers, trucks, flat bent trucks and two truck cars, ten water pumps, three rice cultivators, two large warehouses located at Tudun Wada and Ungogo LGA, Kano, and eight-bedroom apartment." Seed company

In Nigeria, recent findings underscore the difficulties associated with certified seed production. These challenges include diminishing marginal returns influenced by the dynamic effects of climate change and

the unpredictable nature of production input prices, which respond to the instability of the national currency, the naira. Narrowing profit margins are compelling seed companies to reduce their annual seed outputs and adjust their strategies to comply with quality standards, resulting in a reversal of the adoption of certified seeds of improved varieties. In response to the shortage of available certified seeds, NASC is addressing the issue by employing more flexible seed quality assurance approaches. This includes the promotion of intermediate standards such as quality declared seeds, as highlighted in Takeshima et al. (2022a).

8.5. Farmers' demand, capacity, and incentives

More investment in the promotion of new improved varieties and increased exposure and testing among farmers are needed to create demand. Many farmers we surveyed and interviewed were eager to try new varieties and seeds and to witness and identify those that will help them address their challenges and increase their production and incomes.

> *"Of course, we would try new varieties and seeds. Why not? We would love to see how it meets our demands. It will be an experience. If the new brand is better than our local one, we will drop out and embrace the new one. Yes, we will welcome it, no doubt…. Yes, we would welcome another that can surpass silver brand."* Female FGD participant

Large seed companies engage in many diverse promotional activities. They use demos, baby demo packs (trial packs), field days, radio jingles, the internet, social media, leaflets, extension services, marketers, and seed fairs. One large seed company said that in 2021, it conducted more than 500 trials across the country. As seed companies say, "The most impactful of all the promotion activities is the experiential." These promotional efforts need to be expanded through public–private–NGO partnerships. The benefits of improved varieties and frequent replacement of varieties and seeds need to be explained and demonstrated to the farmers.

> *"The main problem is that some farmers find it hard to buy seeds because of the price. When we say a bag of seeds is 20kg and costs 20,000 naira, some complain it's too expensive. Only those who understand the benefits of the new seeds are willing to buy. Some farmers have been using the same type of seeds for a long time, maybe 10 or 20 years, and don't want to change because they think the old seeds are just as good as the new ones. But once they try the new seeds, they realize the difference."*

> *"If there's already a type of crop that people are not using much, we give small free packs of it, like 1kg, to farmers. We ask them to try it alongside their usual crop. If they see good results, they don't need us to tell them to buy more seeds—they will come on their own. They'll notice the difference and want more."* Seed company

Mass media, such as radio, can be very useful in awareness campaigns about new varieties and the importance of quality seeds. But, for communities with zero to minimal exposure and experience on these varieties and seed types, farm demonstrations and small seed samples for farmers to try and experiment on will be crucial to accelerate farmers' awareness and exposure and stimulate their experimentation and demand. The role of farm centers in information dissemination and farmers' education is also important and should be strengthened.

> *"Give small samples for farmers to try…. If other farmers see that they are getting a good yield, they will plant that new seed. It will spread in the communities quickly."* Agrodealer, Kaduna

"We have heard of other varieties on radio; but never seen them yet. We hear on the radio from extension workers how good the products are. They said they blossom richly and have plenty of flour when ground. We also heard that there are Cowpea varieties that are more richly endowed than their 'Silver' type. We cannot get to them. They are never brought to us." Female FGD participant

"I became interested in purchasing seed from extension farm centers because it is formidable and usually certified. It germinates faster, blossoms with fascinating shafts. It cannot be compared with local seeds for its growing speed rate. For example, plant a local seed and give it like ten days to up-shoot; then plant the same but certified seed from farm center. The seed from the farm center will germinate faster and trendier than the local seed despite the ten-day planting gap. When you look at its tassel and silk you notice the difference in quality from what obtained in a local seed. With the right rain, there is no match between the two seeds. Farm center seeds are far ahead. We notice this when extension workers do practical trials with the two seeds on the same farm. We also notice that infestation of pests is minimal on farm center seed." Female FGD participant

9. CONCLUDING REMARKS

This study provides an integrated understanding of the maize and cowpea seed system, including examining the perspectives governing farmers' real-life adoption decisions and behaviors concerning improved varieties and quality seeds. This study also provides measures to better capture seed quality dimensions. These measures indicate wide awareness of improved or modern varieties: 41 percent of maize farmers and 18 percent of cowpea farmers in the two states reported using "improved varieties" from breeding programs in northern Nigeria, where production of maize and cowpea are concentrated. However, varietal replacement was very slow: Improved varieties in farmers' fields were the older bred varieties (released in 2005–2011), and the newer varieties that can offer better traits have not caught up in popularity. The seed quality in farmers' fields was also poor. Most acquired seeds were recycled for about six to eight years on average, way beyond the optimal recycling years. In addition, most were not certified seeds, nor did they show any indication of being quality seeds. We estimate that roughly 18 percent of maize land area and 8 percent of cowpea land area were planted with quality seeds of improved varieties in northern Nigeria in the 2022 cropping season. These percentages are close to the official certified seed production data, applied to maize and cowpea cultivated land area in 2022.

Revisiting the research questions, below we offer some insight on why there was slow varietal replacement and poor-quality seed in farmers' fields and highlight some concluding remarks in entry points to strengthen the seed system.

We found two main challenges to farmers adopting new varieties and better-quality seeds:

1. Not enough seeds were available, especially the initial types needed for production; we suggest more funding and support for early-stage seed production.
2. Farmers did not know enough about these new varieties and quality seeds, implying that both the government and private companies should invest more in promoting and testing these seeds across a wider range of diverse locations and farmer types.

On the positive side, three key complementary factors consistently drove the wide adoption of successful varieties in the past:

1. The seeds were proven to be much better than the old ones.
2. A good supply of high-quality seeds was available.
3. The seeds were effectively promoted to and tested by farmers.

These three factors must be strived for to accelerate the adoption of newer varieties available in the market and encourage the use of quality seeds. The National Seed Policy of 2022 and the National Seed Road Map provide a good framework and guidelines for supporting the seed sector, but proper implementation is crucial.

Beyond just seeds, various factors such as security concerns, poor soil conditions, and high fertilizer and fuel costs hindered farmers and seed actors from expanding production and adopting better seeds. To address these issues, a holistic approach is needed that considers the entire value chain and understands farmers' constraints in producing and marketing their outputs. Smart subsidies, integrated soil fertility management, and breeding for nutrient-efficient and low fertilizer–demanding varieties were some of the options reported by farmers and seed actors.

To promote quality seeds in remote areas, effective strategies include conducting on-farm demonstrations, providing seed samples, and targeted training sessions. Social media and television can be used for awareness campaigns, but radio remains popular, especially among women. However, physical exposure to the seeds through farm demos in local communities is essential for adoption and experimentation. To reach and benefit more women, seed promotion strategies should explicitly include women in farm demos and seed sample distributions. Consumption-related interventions, such as food tasting, cooking demos, or flour/grain mini-pack distribution should include both women and men. Given the role of women in food preparation and storage, it is critical to include women in production-oriented and consumption-oriented interventions and be knowledgeable about these varieties. To reach more female farmers, female-owned seed multiplication and agro-input trading businesses can be promoted and supported.

Finally, besides just promoting the physical seed, it is important to invest in educating farmers about how to manage seeds, adopt good farming practices, and understand the value of using improved varieties and quality seeds. When giving farmers information and seed samples to try, it is essential to include training on how to follow good farming practices, not just hand out seeds without guidance. Government and nongovernment projects and programs should promote experimentation among farmers and encourage farmers to try new things and experiment with different seeds and management practices. This can create a demand for better seeds, ultimately strengthening and transforming the market for seeds.

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ANNEX 1. EVOLUTION OF THE POLICY AND REGULATORY FRAMEWORK FOR THE SEED SECTOR IN NIGERIA

Evolution of Nigeria's seed policies and regulations

Seed policy in Nigeria has its roots in the country's post-independence history and has evolved with technical assistance from international organizations such as the Food and Agriculture Organization of the United Nations (FAO) and the World Bank. The National Seed Service (NSS) was established in 1992 by the Federal Ministry of Agriculture and Rural Development (FMARD) to coordinate the production, distribution, and marketing of improved varieties and quality seeds. The NSS transformed into the NASC in 1999, with the mandate to regulate the seed industry in Nigeria.

In 2019, the country launched a new seed law to promote production and distribution of high-quality seeds, encourage investment in the seed industry, and protect farmers' rights. The law also gives NASC expanded powers to regulate and monitor the quality of seeds produced and distributed in the country under the new seed law, covering activities such as variety development, registration, release, and certification of seeds; seed law enforcement; seed quality control; seed planning, monitoring, and management; seed import and export, and seed production and marketing.

In 2020, The Plant Variety Protection Act 2020 was enacted by the country's parliament to encourage the participation of foreign investors in the country's seed industry.

Before 1990, the seed sector was dominated by the public sector. However, in 1985, the private sector commenced operations in the seed industry following the development and release of the International Institute of Tropical Agriculture's (IITA's) hybrid maize program in 1984. The release of hybrids led to the birth of such companies as Ag-Seed Nigeria Ltd., Zaria (an arm of AG Levent); Temperance Seed Nig. Ltd., Otta; UAC Seed Nig. Ltd. (an affiliate of PANNAR of South Africa), Zaria; Pioneer Seed (A merger between Ag-seed and Temperance Seed Nig. Ltd), Zaria; UTC Seed, Tenti, and Jos.

NASC has private sector representation on its board. It sustains access to breeder/foundation seeds of publicly bred varieties by all accredited seed companies that do not have independent research capabilities. It also facilitates the import of breeding material in collaboration with the national quarantine regulations to develop cultivars.

Nigeria's crop research capacity has grown over time and is leveraging the network of NARIs, agriculture faculties in conventional universities, and universities of agriculture for applied research in specific commodities. In addition, these institutions play a crucial role in seed breeding and development, which is necessary to grow the country's seed system.

Aside from the agriculture ministry, other regulatory agencies also play a role in Nigeria's seed system. The earlier seed policy, published in 2015 with FAO support, precluded the promotion of genetically modified organisms (GMOs), unlike the later version, which encourages their development and cultivation. The country's policy shift also expands the range of stakeholders in the seed value chain to include the National Biosafety Management Agency (NBMA).

The Standards Organization of Nigeria regulates the quality of seeds sold in the country, while the National Agency for Food and Drugs Administration and Control ensures that seed treatments and other seed-related products are safe for use. In addition, the National Centre for Genetic Resources and

Biotechnology (NACGRAB) is responsible for conserving and managing the country's genetic resources and biotechnology.

The private sector, NGOs, and community-based seed producers (CBSPs) are also involved in seed distribution in Nigeria. Private seed companies have emerged, producing and distributing certified seeds, while NGOs promote improved varieties among smallholder farmers. In addition, agrodealers are actively selling seeds at the retail level in many rural communities. Finally, the CBSPs remain a critical component of Nigeria's seed system, accounting for more than 85 percent of the seeds smallholder farmers use annually.

Overall, the various actors in Nigeria's seed system, including government institutions, private companies, NGOs, and informal seed producers and sellers, play complementary roles in ensuring the availability and distribution of quality seeds to farmers nationwide.

Regional context of the National Seed Policy

It is positive to see that the Economic Community of West African States (ECOWAS) has developed initiatives to support agriculture in the region, including the ECOWAS Agricultural Policy (ECOWAP) and regional legislative frameworks. However, it is essential to note that implementation of these policies in member states is lagging, which tends to prevent competitive regional trade. The regulation on quality control, certification, and marketing of plant seeds and seedlings in the region is a step in the right direction toward better seed distribution networks and improved regional trade. The categories of crops covered, including cereals, tubers, pulses, and vegetables, are essential for food security and agricultural production in the region.

The detailed set of procedures for variety release, seed certification, and domestic and regional seed trade provided by the framework is vital for ensuring that farmers have access to quality seeds that can increase their productivity and profitability. The framework also provides a foundation for aligning the seed policy of member countries, which is essential for improving the country-level seed system and enabling regional seed catalog for trade.

National seed policy objectives

- Support varietal development, registration, release, and multiplication of released varieties.
- Improve the quality of seeds sold to farmers.
- Reorient the operations of public sector agencies along commercial lines.
- Encourage private sector participation in seed operations through appropriate policies and promotional activities.
- Increase private sector involvement in certified seed production, processing, and marketing through private seed producers, seed enterprises, seed distributors, and dealers.

Stakeholders and their roles in Nigeria's seed value chain

Output: Develop improved varieties.

Stakeholders: NARIs; universities; International Agricultural Research Centers (IARCs) such as IITA, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Maize and Wheat Improvement Center (CIMMYT), and Africa Rice Centre; private seed companies; the National Plant Quarantine Service (NPQS); and NBMA.

Roles: This category of stakeholders develops new varieties, independently or in collaboration with other partners. These stakeholders also develop products from conventional breeding, participatory selection, transgenics, and gene editing. NBMA is responsible for approving events and stewardship for biotechnology products entering the seed system. NPQS is responsible for approving seed imports (including parent materials) for developing new products.

Output: Release and register varieties.

Stakeholders: Variety Release Committee (VRC), NACGRAB, NARIs, NASC, Agricultural Research Council of Nigeria, Food and Drug Administration, seed companies, farmer organizations, and international agricultural research institutions.

Roles: Assess, release, and register varieties of superior traits in demand by farmers and processors.

NARIs, in collaboration with IARCs, account for more than 75 percent of the released varieties. Recently, NARIs and IARCs are transitioning to licensing private seed companies to enhance the commercialization of released varieties, leading to more than 70 percent of the commercialization of released varieties. Before the shift toward licensing, the commercialization of newly released varieties was less than 20 percent. As a result, more than 80 percent of the varieties released by seed companies emanate from the licenses with NARIs and IARCs, or international NGOs such as the African Agricultural Technology Foundation (AATF) in the case of the PBR Cowpea and Tela/Tego Maize hybrids.

NACGRAB coordinates the variety release/registration process, while NASC maintains a register of seed companies and their portfolios.

The variety release committee meets twice a year to consider nominations for release. Development partners and IARCs have been instrumental in (facilitating) the regularity of the meetings.

Output: Produce breeder seeds (BS).

Stakeholders: NARIs, IARC, and seed companies; IAR, IAR&T, National Cereals Research Institute (NCRI), and National Root Crops Research Institute (NRCRI).

Remarks: NARIs and IARCs are responsible for producing BS and seed companies recently for their proprietary products.

Output: Produce foundation seeds (FS).

Stakeholders: NARIs, IARCs, private seed companies, and universities (having proprietary rights).

Remarks: In addition to the NARIs, three seed companies have licenses to produce FS—Premier Seed Limited, Value Seed Limited, and Eco BasicSeed Limited. Maize is essentially the focus of these companies, although PBR Cowpea is part of Eco BasicSeed Limited's portfolio.

Output: Produce certified seed (CS).

Stakeholders: private seed companies, ADPs of state governments, CBSPs/NGOs.

The certified seed production capacity of most ADPs has largely collapsed. CBSP appears to be taking up the vacuum created by the dwindling effectiveness of the ADPs.

Output: Distribute and market certified seeds.

Stakeholders: seed companies, community-based organizations (CBOs)/NGOs, and agrodealers.

Roles: Market seeds and render product stewardship to boost certified seed adoption.

Distribution and marketing are perhaps one of the weak points in the seed value chain in Nigeria, factors that are limiting the adoption of improved varieties to less than 15 percent.

Output: Ensure seed quality, regulate and develop seeds.

Stakeholders: NASC leads policy co-creation, implementation, evaluation, and review processes.

Roles: Conduct seed field inspection, certification, and quality control.

Output: Seed extension/seed promotion.

Stakeholders: National Agricultural Research and Extension System (NARES), NARIs/ADPs, NGOs.

Roles: Promote awareness and adoption of improved varieties and quality seeds. Some of the NARIs/ADPs monitor the adoption and impact assessment of seed technology adoption.

NARIS, federal and state ministries of agriculture, ADPs, NGOs (for example, AGRA, GIZ, religious missions, Winrock International, Catholic Relief Services), cooperative extension centers of the universities of agriculture, seed companies, NASC, financial institutions, national and state emergency management agencies, media houses, cultural troupes, and movie makers.

Roles: Provide training, conduct demos and on-farm trials, and develop extension (promotion) support materials (guides, manuals, bulletins, leaflets, posters, billboards, radio/TV jingles, and programs).

Output: Provide finance/credit support.

Stakeholders: Bank of Agric, risk mitigation institutions (Nigeria Risks Sharing Agricultural Lending [NIRSA], National Agricultural Insurance Corporation [NAIC], Leadway Insurance Plc), commercial banks, development partners, and others.

Role: Provide finance or mitigate production/facility risks.

Risk coverage for seed enterprises is linked to production, although it is uncommon because of the lack of structured financing products suitable for the sector. The loan tenure of most financing institutions has yet to accommodate the long moratorium requirements of the seed industry primarily. It takes between 24 and 36 months to produce an appreciable quantity of certified seed using BS/FS.

Output: Handles seed imports and exports.

Stakeholders: NASC, NPQS, seed companies, and the federal government.

Roles: NPQS issues permits for importing seeds, while NASC grants approvals of the seed class to import from other countries. In addition, the NPQS processes phytosanitary certification and documentation.

Regarding exports, NASC and NPQS, respectively, issue the seed passport and phytosanitary certificates.

Impact and bottlenecks in seed policy and regulations

Impact of seed policy[4]

- Private-sector participation in the seed industry increased significantly between 2012 and 2016.
- There has been an increased number of accredited seed entrepreneurs in Nigeria, rising from 36 in 2010 to 157 in 2016, making Nigeria the leading seed industry in West and Central Africa, with more than 200 applications at various stages of approval/accreditation.
- The opening of these new businesses has created more than 3.5 million seasonal jobs across the seed value chain in Nigeria.
- 14.3 million farmers were reached with certified seeds of improved varieties of rice, sorghum, maize, and soybean, among others, using an e-wallet.
- More than 43 seed companies now own modern state-of-the-art seed processing plants.
- More than N33 billion was invested into the Nigerian economy through sales of improved seeds between 2012 and 2016.

Challenges

- Sometimes, there is confusion regarding the seed import roles of NQS and NASC.
- There have been tensions regarding the promotion/abuse of community-based seed schemes (CBSS).
- There is low adoption of improved varieties and quality seeds.
- Digitalization of seed quality assurance remains low.
- The internal seed quality control infrastructure is weak at the individual seed company level.
- The expansion of seed companies places enormous pressure on the lean number of seed inspectors.
- The export of seed/regional seed movement has too many hiccups.
- The incidence of fake seeds/adulteration of seeds is on the rise.
- There is high cost of or poor access to financing.
- Poor market development leads to the closure of many seed companies.
- There is a lack of sustainable supply of early-generation seeds.
- How do we overcome the sentiments regarding biotechnology (GMO) products to boost their adoption?
- What strategy would work best to ensure the formalizing of CBSS operations?

[4] NASC Annual Report

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