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Seed Certification and Maize, Rice and Cowpea Productivity in Nigeria

An Insight Based on Nationally Representative Farm Household Data and Seed Company Location Data

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Abstract

Despite the potential importance of seed quality to agricultural productivity growth, many governments in sub-Saharan Africa lack the capacity to expand quality assurance systems even where there is expressed interest. This study aims to evidence the value of quality assurance systems with an analysis of efforts to produce and distribute certified seed in Nigeria. We assess the associations between quantities of certified seeds produced and spatial variations in production locations proxied by headquarter locations of seed companies producing certified seeds, on the one hand, with spatial variations in the use of certified seed, yields, and output at the farm level, on the other hand. Our analysis covers three crops that are important to food security in Nigeria: maize, rice, and cowpea. Our analysis integrates information on seed quantities produced and locations of seed companies with nationally representative panel data from a survey of farm households and spatially explicit rainfall and temperature data. We find a positive relationship between certified seed production in proximity to farm households and farm-level use of certified seeds, yields, and output, although this effect is diminishing at the margin. These diminishing marginal effects may be partly due to two factors. First, the yield gains from certified seeds tend to vary considerably within each state, suggesting that either quality issues persist in the seed supply chain or farmers are not using complementary inputs or appropriate management techniques when using quality seed. Second, it may be that as certified seed becomes more available to farmers, its use spreads from higher-return farms to lower-return farms, thereby diminishing the gains on the extensive margin. Although more rigorous assessments of causal effects and cost-effectiveness are needed to validate these findings, these results are consistent with the hypothesis that there are diminishing returns to seed quality assurance. Policymakers, regulators, and seed providers may benefit from identifying optimal, crop-specific target quantities or rates for certified seed production rather than aiming for certification of all seed produced in a market.

Keywords: Certified seeds, seed company locations, maize, rice, cowpea, Nigeria

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1 Background

Seed quality assurance systems have been integral to seed sector development in many lower-income countries. Seed quality assurance ensures that the physiological characteristics of the seed and the physical characteristics of the seed packet or lot meets some desirable set of standards and is thus able to ensure that farmers realize the genetic characteristics embodied in the seed (Cromwell et al. 1992). Seed quality assurance requires careful assessment of variables such as the presence of pests, diseases, and debris at or below acceptable tolerance thresholds; the percentage share of seeds that will germinate when sown; moisture content; and genetic consistency.

Seed quality regulations have been central to seed sector policies (Pray & Ramaswami 1991) and seed supply chain processes and activities (FAO 2015) in developing countries since at least the Green Revolution of the late 1960s. Seed quality regulations have expanded to many more developing countries and crops since then, yet their effectiveness depends on a number of factors: whether the crop is regulated; the type, standard, or class of quality being pursued; the type of seed provider; the capacity and quality of the regulator; and other factors. While "certified" seed is the most commonly referenced seed class or type in most developing countries, some countries permit other classes such as "quality-assured", "quality-declared", "truthfully labeled", and "farmer-managed" seed, each with its own set of standards and requirements.

In recent years, the Government of Nigeria and many of its seed sector stakeholders have been keen to expand the supply of quality seed, including seed that is certified by the National Agricultural Seeds Council (NASC), an agency of the Federal Ministry of Agriculture and Rural Development that was established in 2007 in line with the 1992 National Agricultural Seeds Act (FMARD 2015, 2021; NASC 2022a). The country has pursued a relatively narrow seed quality assurance system, for example, focusing on strict certification standards without recognizing more intermediate seed classes such as quality declared seeds (Kuhlmann et al. 2018). To date, there is relatively little information or analysis of the effects of seed quality assurance on use rates, yields, or output, and thus very little insight on the optimal levels and rates at which seed should be regulated for quality.

Understanding these aspects is important because the design and implementation of a seed quality assurance system can be a resource-intensive undertaking with high marginal costs (Lillie & Budhiyono 1995; Opoku 2017), as evidenced in other countries in East Africa (e.g., ISSD 2017; Mastenbroek et al. 2021), West Africa (e.g., Miklyaev et al. 2017), and North Africa (Kugbei et al. 2000, p.66) as well as Asia (e.g., Lillie & Budhiyono 1995)). At the same time, the returns to quality seed use may vary considerably depending on agroclimatic conditions and farmer characteristics, especially where these conditions and characteristics are highly heterogeneous (e.g., Sheahan & Barrett 2017; Suri & Udry 2022) or where supply chain issues affect quality (e.g., Barriga & Fiala 2020).

This study explores the value of quality assurance systems with an analysis of certified seed production and distribution in Nigeria. We assess the associations between i) the quantity of certified seeds produced and the spatial variations where they are produced and ii) spatial variations in the use of certified seeds and/or improved varieties, yields, and output. We also assess the yield effects of certified seed use and their relationship with agroclimatic and socioeconomic conditions. Our analysis combines nationally representative farm-household survey panel data from the Living Standard Measurement Study – Integrated Survey on Agriculture (LSMS-ISA) (NBS & World Bank 2019) with spatial data on the headquarter locations of seed producing organizations, most of which are seed companies based on the NASC's terminology, and the quantity of certified seed that they produce, and spatially explicit rainfall and temperature data. We focus on three crops—maize, cowpea, and rice—which, according to the 2018 LSMS-ISA survey round, were the 2nd, 4th, and 8th most widely cultivated crops in Nigeria, respectively.

Results show that there are nonlinear returns to certified seed production are partly due to significant heterogeneity in the yield effects of certified seeds. We find diminishing returns to certified seed use at the extensive margin: certified seed use may be yield-enhancing among better-endowed, higher-return farms, but tends to diminish when used on less-endowed, lower-return farms. These results underscore the importance of considering the returns and costs carefully in targeting the extent of seed certification efforts.

This study contributes to various strands of literature on seed sector development and agricultural input markets. By providing quantitative insights into the returns to quality seed, we complement existing studies that highlight the importance of seed sector policy reforms and seed system interventions (Pray & Ramaswami 1991; Cromwell et al. 1992; FAO 2015; Spielman & Kennedy 2016; Nabuuma et al. 2022). We also inform the debate over alternative quality assurance systems in the seed sector (Tripp & Louwaars 1997; ISSD 2017; Kuhlmann & Dey 2021; Spielman et al. 2021). Our study also contributes to recent literature on the economics of certified seeds (Auriol & Schilizzi 2015; Mastenbroek & Ntare 2016; Opoku 2017; Maredia et al. 2019; Mastenbroek et al. 2021) and the impacts of subsidizing certified seeds (Wossen et al. 2017; Abate et al. 2018). Finally, our study supplements various others that assess seed sector policy issues in Nigeria (USAID 2016; NASC & SEEDAN 2020; Waithaka et al. 2019; Mabaya et al. 2021; Olisa et al. 2022).

The remainder of the paper is structured as follows. Section 2 describes seed sector policies in Nigeria, with a particular focus on certified seed production. Section 3 presents our empirical approach and data. Section 4 presents our results and discusses their implications for policy and regulation. Finally, Section 5 concludes with thoughts for topics for future research.

2 Certified seed production policy issues in Nigeria

Seed certification has been the primary tool for assuring seed quality in Nigeria over the last few decades for a limited number of crops. Until 2019, the main legal documents guiding the development of the seed sector in Nigeria were the National Seeds Decree of 1992 and the National Agricultural Seeds Act, Cap N5 of 2004 (NASC & SEEDAN 2020). However, the National Agricultural Seeds Council Act 2019 empowered NASCs to provide legal backing for seed certification (NASC & SEEDAN 2020). The Seed Certification, Quality Control, Crop Registration and Release Department (SCQCCR&RD) within NASC is statutorily responsible for quality assurance and seed certification (NASC 2017). Seed Certification Officers are located in each state of the federation, including the Federal Capital Territory (NASC 2017).

The Government of Nigeria is strategically focused on expanding certified seed production in response to guidance provided by the National Seed Policy 2015 and the updated draft of 2021 (FMARD 2015; 2021). In fact, significant efforts were made between 2013 and 2015 to produce certified seeds for maize, rice, and several other crops on an unprecedented scale relative to the quantity of seed used in previous years. The private sector has played a significant role in these scaling efforts, accounting for 95% or more of total certified seeds produced in the country. A much smaller fraction of certified seed is supplied by other entities like community-based seed organizations (CBOs) (NASC 2017, 2020). CBOs also produce small quantities of quality declared seeds (QDS) for sale within their communities, under NASC supervision (Iorlamen et al. 2021).

For most crops, however, the quantities of certified seed supplied to Nigerian farmers are only a fraction of the total supply of seed from all sources. Seed certification capacity in Nigeria is extremely limited: the country employs only 50 seed inspectors and 75 seed certification officers who are seconded to each Agricultural Development Project (ADP) area in 37 states (Bentley et al. 2011; Waithaka et al. 2019). Nigeria's agricultural land area is not only large—35 million hectares of arable land make it one of Africa's largest agricultural countries—but also exceptionally diverse in agroecologically and socioeconomically. This means that seed and planting materials for a wide range of crops and seed producer types could, in theory, be subject to seed certification (**Table 1**). Despite exceeding several other countries, the figure for Nigeria is still on the lower end when measured by per million agricultural workers.

Table 1. Seed certification capacity in Nigeria and other selected countries (years vary)

Country	Seed inspectors	Arable land (1,000 ha)	Population employed in agriculture based on ILO definition (1,000)[a]	Seed inspectors per million ha of arable land	Seed inspectors per million agricultural workers
Nigeria	**60**	**35,000**	20,225	**1.7**	**3.0**
Burkina Faso	45	6,000	1,868	7.5	24.1
Burundi	7	1,200	4,238	5.8	1.7
Ethiopia	32	16,195	34,605	2.0	0.9
Ghana	43	2,513	3,685	17.1	11.7
Kenya	50	5,800	12,562	8.6	4.0
Liberia	1	500	922	2.0	1.1
Madagascar	60	3,000	8,712	20.0	6.9
Malawi	37	3,600	5,798	10.3	6.4
Mali	60	6,411	4,159	9.4	14.4
Mozambique	25	5,650	8,966	4.4	2.8
Rwanda	8	1,152	3,920	6.9	2.0
Senegal	21	3,200	1,198	6.6	17.5
South Africa	180	12,000	881	15.0	204.3
Tanzania	48	13,503	17,340	3.6	2.8
Uganda	7	6,900	11,759	1.0	0.6
Zambia	118	3,800	3,231	31.1	36.5
Zimbabwe	60	4,000	4,425	15.0	13.6

Source: Number of seed inspectors from Mabaya et al. (2021), Waithaka et al. (2019, 2021). Arable land and employment in agriculture are from FAOSTAT (2022).

[a] Employment in agriculture here corresponds to the ILOSTAT indicator "Employment by sex and economic activity -- ILO modelled estimates, Nov. 2020 (thousands) -- Annual" for the agriculture, forestry, and fishing sector defined by Section A of ISIC classification. Employment comprises all persons of working age who during a specified brief period, such as one week or one day, were in the following categories: a) paid employment (whether at work or with a job but not at work) or b) self-employment (whether at work or with an enterprise but not at work) (FAOSTAT 2022).

Seed certification in Nigeria has also tended to focus on somewhat older varieties without commensurate certification of newer varieties. For example, FARO 44 constituted the majority of certified rice seed sold in Nigeria during the 2013–2015 period (and even in recent years). Yet the variety was introduced in Nigeria in the 1990s, and many of its desirable traits have been improved on or surpassed by newer varieties (Gyimah-Brempong et al. 2016). As such, the returns to using certified seed of a higher physical quality and cost may be overshadowed by the forgone genetic gains proffered by newer varieties and may represent an inefficient allocation of scarce farm-household budgets to certified seed rather than other inputs and technologies.

Limited capacity in Nigeria can lead to a significantly high costs for seed certification. There are generally few studies of seed quality assurance costs, including the World Bank's

"Enabling the Business of Agriculture" study which provides useful data on varietal registration and seed quality assurance practices, covering 101 countries in its 2019 edition (World Bank 2019), but does not provide data on seed certification costs.[1] However, a study conducted in Ghana indicates that the average cost of producing 1 kilogram of certified cowpea seed was estimated to be twice the average cost per kilogram of producing cowpea grain (Opoku 2017). Other studies capture the hidden transactions costs of seed certification. Estimates from Indonesia suggest the actual rice seed certification costs during the 1990s were 33,000 Rupees/ha (about USD $77/ha), in contrast to official certification costs of 1,500 Rupees/ha (about $3/ha) (Lillie & Budhiyono 1995, p158). Similarly, in Tanzania, actual field inspection costs and seed health testing costs for amaranth in 2015 were 835,500 and 80,000 Tanzania Shilling/ha (about $418/ha and $40/ha)—figures that are much higher than the official fee schedule of 18,000 and 24,020 Tanzania Shilling (about $9/ha and $12/ha). Other studies estimate the cost of quality seed in relation to the market price of the final commodity at the farmgate. For example, Maredia et al. (2019) suggest that quality seed for beans or cowpea should cost no more than 1.5 times the price of the relevant grain, while Morris (1998) suggests that hybrid maize seed should be 5 to 10 times the price of the relevant grain, depending on the maturity of the market. Because direct estimates of seed certification costs in Nigeria are not readily available but are likely to be substantial, assessing the patterns of productivity effects of certified seeds can inform how efforts in seed certification should be prioritized.

3 Analytical approach

3.1 Data and key variables

Our farm household-level data are from four survey waves of the LSMS-ISA: 2010/11, 2012/13, 2015/16, and 2018/19 (see NBS & World Bank (2019) for additional details on these survey waves). Taken together, these waves provide a nationally representative panel dataset of 5,000 households in total. In the first three waves, 3,493 of the original 5,000 households responded, and, in the fourth wave, 1,507 households (NBS & World Bank 2016, 2019).[2] Within these panels, our analysis focuses on agricultural households, which account for approximately 60 percent of the samples in each wave. While part of our certified seed production variables varies at local government areas (LGA) levels, we focus our analyses at household levels. As explained below, time-invariant household-fixed effects also controls for LGA-fixed effects that include other LGA-confounders.

Survey data are supplemented with information on quantities of certified seeds produced by seed companies between 2007 and 2017 (NASC 2009, 2011, 2014, 2017) and the locations of their headquarters (State) (NASC 2022b). For each of these years, the NASC annual reports describe the quantity of certified seeds for different crops (including maize, rice, and cowpea) by each seed company.

Finally, historical and spatial data on rainfall and temperature are extracted from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) (Funk et al. 2015) and National Oceanic and Atmospheric Administration (NOAA) (2022), respectively, using the geographic coordinates of enumeration areas (EA) where respondents reside. The historical

[1] The EBA provides two legal data points on (1) whether private seed companies or third parties (for example, private laboratories) can certify seed, and (2) whether the national seed authority publishes a fee schedule for seed certification costs.

[2] The original 5,000-panel households consist of 10 households that were randomly selected in the first wave from each of 500 enumeration areas (also randomly selected from among all enumeration areas defined by the NBS) and reinterviewed in Waves 2 and 3. The 1,507 households in Wave 4 were selected from 159 of the original 500 enumeration areas (NBS & World Bank 2019).

average of windspeed at 10 meters above the ground is extracted from Climatic Research Unit (CRU) (2022), while various soil parameters are extracted from FAO et al. (2012).

3.2 Empirical model

Our empirical approach relies on a simple farm-level panel fixed effects model. Specifically, we estimate,

$$y_{kijt} = \alpha + \beta_1 S_{kjt} + \beta_2 S_{kjt}^2 + \gamma X_{ijt} + u_{kij} + \varepsilon_{kijt}. \quad (1)$$

The key continuous outcome variable is yield (ton/ha) for crop k by farm household i in LGA/state j at year t (y_{kijt}) while discrete outcome indicators include self-reported use of improved and/or certified seeds. Assessing all these outcomes can partly mitigate the sensitivity of our results to definitional ambiguity, as further discussed in Section 3.3 below.

Each of these indicators are regressed on a proxy variable for certified seed for crop k supplied before the beginning of year t by seed companies based in LGA/state j where farm household i is located (S_{kjt}) and on its squared term (S_{kjt}^2), as well as other time-variant exogenous control variables (X_{ijt}) (see below). The variable S_{kjt} is standardized to a per capita base, using the state's population in the most recent population census (National Population Commission of Nigeria 2016).[3] Notations α, β, γ are estimated parameters; u_{kij} is a parameter that control for time-invariant fixed effects of crop, household, and LGA/state all-combined; and ε_{kijt} is the idiosyncratic error term. The parameters β_1 and β_2 capture the marginal effects of proxy variables for certified seed quantities, and by including S_{kjt}^2, we also focus on whether the marginal effects significantly change at the intensive margin. We include S_{kjt}^2 as we suspect that the marginal effects may decline due to significant heterogeneity in the patterns of certified seed use and its yield effects, which we discuss in the subsequent sections. Similar models assessing the effects of district or state level variables on household-level outcomes have been used in previous studies (e.g., Ramaswami et al. 2002; Takeshima et al. 2022).

Proxy variable S_{kjt}

We proxy access to certified seeds through the quantity of certified seeds produced by companies headquartered in the state. While this is obviously a crude proxy, various studies also provide supporting anecdotal evidence for its general suitability. First, in Nigeria, most seed companies sell seeds through agrodealers or directly to farmers, as well as to governments (Mabaya et al. 2021). Because seed companies often need to monitor payments from agrodealers, and poor road infrastructure also raises transactions costs from moving seeds across wide geographic space, it may make sense for companies to procure and sell more seeds locally rather than regionally (Bentley 2011). Second, many seed companies, including major ones like Premier Seed Ltd., have at least one warehouse located at company headquarters where they store seeds (Bentley 2011), suggesting that many headquarters' locations indeed signify where their companies' certified seeds are physically stored. Thirdly, seed companies have accounted for a significant share of certified seed produced in Nigeria, especially since the 2010s, often accounting for 95% or more, while former producers like ADP have significantly reduced their shares (NASC 2017). In an alternative specification, we re-run Equation (1) controlling for the quantity of certified seed produced in the LGA instead of in the state.

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[3]We standardize by population size in LGA/state, rather than the size of crop areas or number of producers within LGA/state, because accurate information for the latter is not available.

In model (1), we argue that the variable S_{kjt} is exogenous to farm-household level outcomes y_{kijt}, after controlling for combined time-invariant fixed effects of crop, household, and LGA/state (u_{kij}), and other exogenous factors X_{ijt}. This is because, as described above, S_{kjt} depends on the quantity of certified seeds produced during the previous year ($t-1$) and more likely to be pre-determined. This model is in a reduced form which combines both effects on farm households' latent demand and their capacity to obtain the seeds. As described later, we also assess a model where the actual use of certified seeds at farm household level is treated as endogenous to y_{kijt}.

Other control variables X_{ijt}

Variables X_{ijt} include a similar set of factors as in previous studies conducted in Nigeria (e.g., Takeshima 2019; Takeshima et al. 2022). Specifically, they consist of household demographics; household wealth and capital; input markets; infrastructure access; community-level shocks; and agroclimatic condition. Household demographics variables include the number of members differentiated by gender and age group (children aged 14 years or younger, working-age members aged between 15 and 60, and elderly aged 61 years or older), as well as gender and age of the household head.

Wealth and capital variables include human capital (years of education completed by the household head), household asset values, whether receiving remittances, whether having non-farm incomes, size of exogenous farmland endowment (owned by the household or distributed by the local chiefs) as well as the number of plots owned. Wealth variables include the value of livestock owned and the value of agricultural equipment owned, both of which are evaluated at their market prices.

Proxies for input markets include the local prices of key inputs other than seed, including fertilizer and labor, as well as access to agricultural extension. Access to infrastructure is captured by physical distance to the nearest market and administrative center. Proxies for community-level shocks include community representatives' perceptions of the incidence of key agricultural shocks (drought, flood, crop diseases/pests, and livestock disease) in the community during the past 12 months, as well as several other positive and negative events.[4]

Agroclimatic variables include the z-score of current annual rainfall and average temperature, which we constructed by comparing their historical averages and standard deviations between 1980 and 2009 (one year before the first wave of LSMS-ISA). Year dummies are also included to control for year-specific effects and are interacted with six geopolitical zone dummy variables.

Heterogeneity in the use and yield effects of certified seeds

Equation (1) assesses the relationship between S_{kjt} and yield or seed use patterns at the farm level. We also conduct supplementary analyses that provide some insights into particular effects of S_{kjt} in (1) by further investigating the effects of key time-invariant variables (specifically, agroecological variables) on certified seed use and its effects on yield. Specifically, we first estimate

[4]Positive events include development project implemented in the community, new employment opportunity, new health facility, new road, new school, improved transportation services, on-grid electricity, off-grid electricity. Negative events include human epidemic disease, sharp change in prices, massive job lay-offs, loss of key social service(s), power outage(s), and any other negative incidents.

$$\hat{u}_{kij} = \alpha + \beta_Z \cdot Z_{ij} + \varepsilon_{kij}. \quad (2)$$

where $\hat{u}_{kij}$ is the predicted value of time-invariant fixed effects on the use of certified seeds estimated in Equation (1) with dependent variable y_{kijt} being the binary variable indicating whether the respondent i used certified seed in year t. Prior studies use similar specifications for Equation (2) to estimate the associations between time-invariant fixed effects and other time-invariant variables (e.g., Dercon 2004; Jacoby & Minten 2009; Takeshima 2019). Z_{ij} is the set of time-invariant agroecological variables, namely soil parameters, the historical average of annual rainfall and annual average temperature, as well as wind speed, which is considered an important variable affecting yield in Africa (Tittonell & Giller 2013). Unlike equation (1), which estimates effects of time-variant factors on certified seed use, Equation (2) estimates the effects of time-invariant factors on certified seed use.

We then estimate

$$y_{kijt} = \alpha + \beta_C \cdot C_{kijt} + \beta_{CZ0} \cdot \left(C_{kijt} \cdot Z_{ij}\right) + \beta_{CZ1} \cdot \left(C_{kijt} \cdot X_{ijt}^*\right) + \beta_Z \cdot X_{ijt} + \upsilon_{kij} + \varepsilon_{kijt} \quad (3)$$

where y_{it} is the log of yield, and C_{kijt} is a binary variable indicating whether the household used certified seeds for each crop. The time-invariant agroecological variable Z_{ij} is defined as above, while X_{ijt}^* is a subset of the time-variant exogenous variable X_{ijt}. Equation (3) estimates the heterogeneous effects of certified seed uses on yield, with heterogeneity depending on Z_{ij} and X_{ijt}^*. Specifically, X_{ijt}^* includes farm size, agricultural capital, household asset, and gender of household head—the latter being time-variant because the household head may change due to death, emigration, or other factors.

In Equation (3), C_{kijt} and all interacted variables are potentially endogenous, because C_{kijt} is one of the dependent variables y_{kijt} in Equation (1). We therefore estimate Equation (3) with both OLS fixed effects (where C_{kijt} and interacted variables are treated as exogenous), and an instrumental variable (IV) fixed effects method, where C_{kijt} and interacted variables are potentially endogenous and instrumented using $S_{kjt} \cdot X_{ijt}^*$ and $S_{kjt} \cdot Z_{ij}$ as excluded IVs.

3.3 Descriptive summary

Certified seed production

Figure 1 and Figure 2 illustrate the trend of certified seed production in Nigeria for target crops in recent years and their variations across regions. Figure 1 shows that certified seed production for maize and rice has increased significantly since 2012 compared to previous years. This surge in production in 2013 and 2014 was likely due to a shift in focus under the then-administration's Agricultural Transformation Agenda (ATA), which promoted the significant increase in the supply of certified seeds of maize and rice. The production declined somewhat since 2016 under the new administration. Although the volume of certified seed production has dropped from its peak in 2014, it has remained above pre-2013 levels since then. In recent years, certified seed production has been largely concentrated in maize (particularly open-pollinated varieties (OPVs)) and rice (particularly lowland varieties). To interpret the scale of production, the right panels of Figure 1 show the ratio when quantity of seed used in the country is set at 100 based on FAO (2022). Seed quantity from FAO (2022) is generally follows the same order of magnitude from estimates from LSMS-ISA which is not used here due to large standard errors. While Figure 1 (upper right) may not show the actual share (%) of seed used in the country, due to potential wastage before use or export, it still shows the potential economic significance of certified maize and rice seed production in Nigeria. Using this index, certified seed quantity has amounted to 30 or more since 2013 for both maize and rice (Figure 1, upper right). Certified cowpea seed production remained low relative to maize and rice but was significantly higher in 2020 compared to previous years (Figure 1, bottom panel). The reason behind the greater production of certified cowpea seed in 2020 is unclear, although it might have been partly driven by the Nigerian government's interest in promoting cowpeas as an export crop under The Agriculture Promotion Policy implemented between 2016 and 2020 (FMARD 2016).

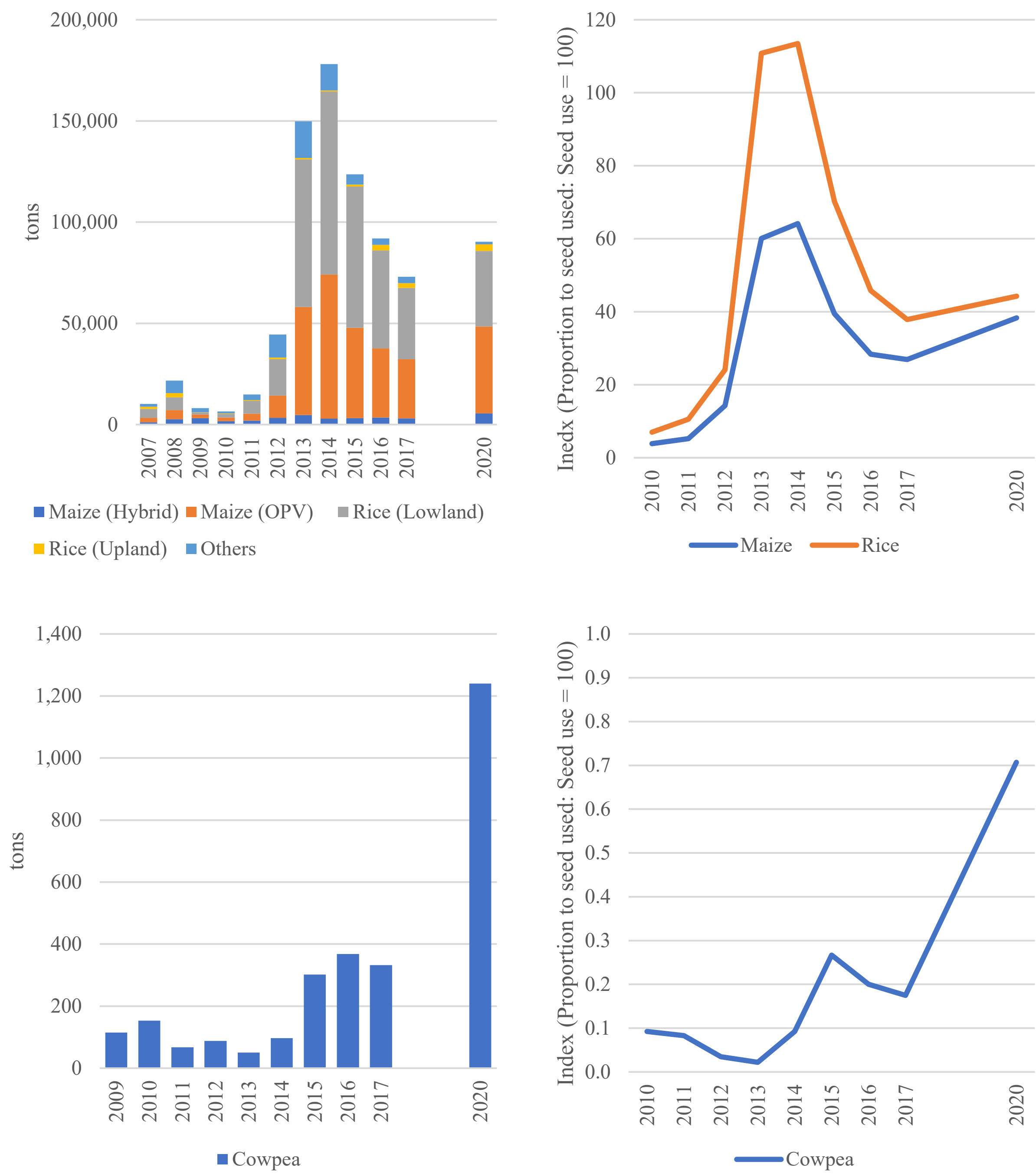
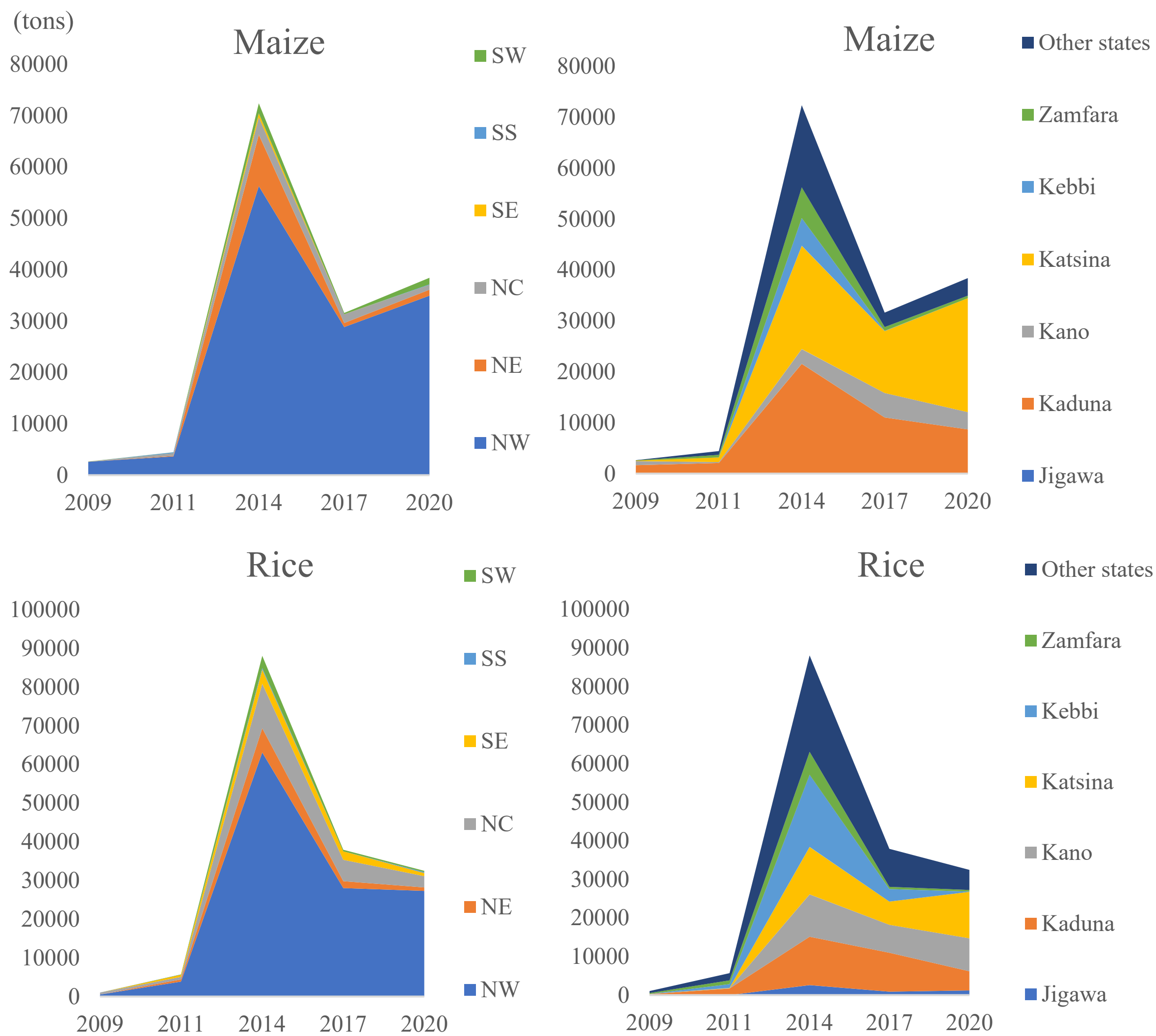


Figure 1. Quantity of certified seeds produced in Nigeria
Source:
Authors' calculations based on NASC (2017) and NASC (2022b) in left-hand side panels, and FAO (2022) in right-hand side panels.



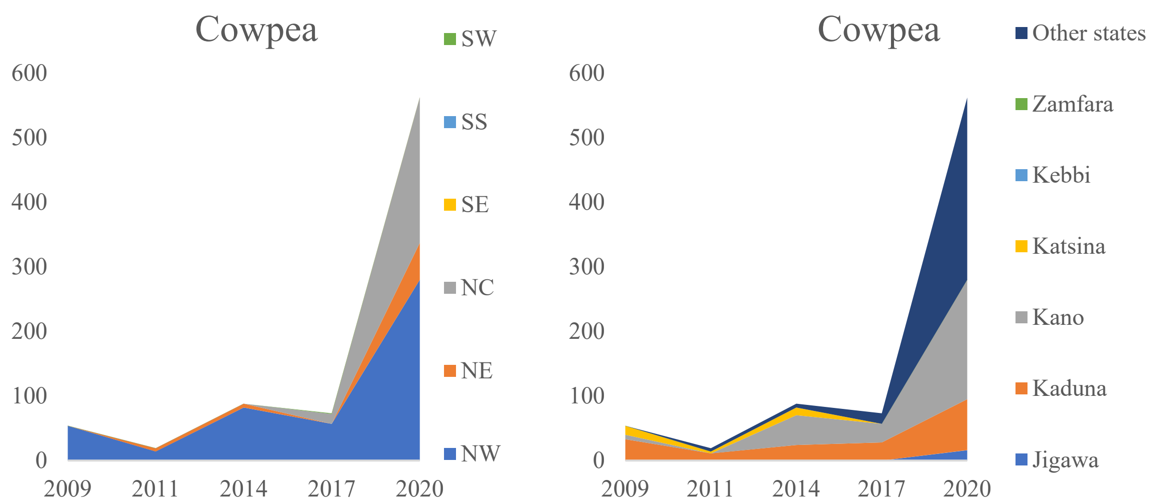


Figure 2. Quantity of certified seeds produced in Nigeria (tons), by geopolitical zones and major states of seed company headquarters

Source: Authors calculations based on NASC (2017). NW = Northwest; NE = Northeast; NC = North Central; SE = Southeast; SS = South South; SW = Southwest

Figure 2 illustrates the distribution of certified seed production for target crops across geopolitical zones (left panel) and states (right panel). The spatial distribution of certified seed production by state and year is illustrated in Appendix Figure 4. The Northwest zone has accounted for a significant majority of certified seed production and fluctuations over time for both maize and rice, while both the Northwest and North Central zones have by far the largest share for cowpea. The dominance of the Northwest zone is in stark contrast to the more dispersed distribution of production areas across geopolitical zones (Appendix Figure 5). For example, the Northwest typically accounts for only about 20 percent of total seeds used in the country, but the size of cultivated land in the Northwest is comparable to (or somewhat less than) that of the Northeast, North Central, and Southwest zones. This suggests that the Northwest zones have accounted for a disproportionate share of certified seed production based on seed company locations. The Northwest zone's disproportionately high share in certified seed production has also been at odds with the trends of general public-expenditures for agriculture (PEA) by the state and local governments. For example, figures in Appendix Figure 6 show that, the per capita PEA in the Northwest is not significantly higher than most other geopolitical zones and has fluctuated much more modestly between 2007 and 2015 compared to certified seed production.

Farm household variables

Table 2 shows the household-level outcome variables. Outcome variables indicate that most respondents exhibit low yield and limited use of modern or certified seeds. We use the term "improved varieties", instead of "improved seeds" as is named in LSMS-ISA data, to avoid confusions with "certified seeds". Here, "improved varieties" are defined as varieties that have some better qualities/traits added to it by a farmer or a plant breeder. These new traits can include higher yield, drought resistance, or pest resistance, among others (NBS & World Bank 2019). Similarly, "certified seeds" reported at the farm household level here are defined as seeds that have been approved for sale and planting by the appropriate seed certification authority such as the Ministry of Agriculture (NBS & World Bank 2019).

Importantly, definitions of "improved" and "certified" seeds by farm household are still ambiguous in LSMS-ISA data as they rely on respondents' perceptions, rather than based on scientific verification. In some cases, respondents mention that seeds are "certified" but "not improved". Because of this ambiguity, we consider all three combinations (i.e., improved varieties, certified seeds, or improved and certified seeds).

Table 2 shows that use of improved varieties and certified seeds (based on respondents' perceptions) is quite rare for all three crops. It is worth noting, however, that the use of hybrid seeds is considerably lower than the use of improved varieties, suggesting that, according to respondents' perceptions, most improved varieties or certified seeds are OPVs rather than hybrids.

Table 2. Outcome variables

Variables	Crops	Average (all 4 rounds)	Median (all 4 rounds)	Standard deviations (all 4 rounds)
Yield (tons / ha)	Maize (OPV and hybrid)	2.063	1.172	2.374
	Rice	2.723	1.976	2.357
	Cowpea	1.304	0.700	1.685
Using improved varieties (yes = 1)[a]	Maize (OPV and hybrid)	0.153	0.000	0.361
	Maize (Hybrid)	*0.054*	*0.000*	*0.227*
	Rice	0.133	0.000	0.340
	Cowpea	0.058	0.000	0.234
Using certified seeds (yes = 1)[a, b]	Maize (OPV and hybrid)	0.176	0.000	0.380
	Maize (Hybrid)	*0.027*	*0.000*	*0.161*
	Rice	0.202	0.000	0.402
	Cowpea	0.292	0.000	0.498
Using certified seeds (yes = 1)[a, c]	Maize (OPV and hybrid)	0.072	0.000	0.259
	Maize (Hybrid)	*0.012*	*0.000*	*0.107*
	Rice	0.070	0.000	0.255
	Cowpea	0.035	0.000	0.183

Source: Authors based on NBS & 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 as "improved varieties" or "other seeds (traditional, local)"
[c]Use of certified seeds = 1 if the respondent indicated so and only if the respondent called them as "improved varieties"

Data from the most recent survey round (Wave 4) also shows several interesting patterns related to seed use. First, the share of self-reported use of improved varieties is higher on male-only managed plots relative to plots that are either female-only or jointly managed (Appendix Figure 7). Second, among respondents who reported using improved varieties, more than 60 percent reported that the improved varieties used were certified, and 20–30 percent did not know whether the seed was certified. (Appendix Figure 8). Third, yield potential has remained the dominant reason for using improved varieties among both female and male farmers (Appendix Figure 9).

Appendix Table 8 provides the descriptive statistics of exogenous variables. For our sample, the quantity of certified seeds produced by seed companies located in the same state as respondents, is typically 1 kg per capita per year for maize and rice and 0.02 kg for cowpea. Households surveyed are primarily asset- and resource-poor smallholders, mostly male-headed, somewhat remotely located from the markets. In survey years, respondents were typically in areas that experienced above-average rainfall and temperature compared to historical averages during the period between 1980–2009.

4 Results

Main results

Overall, our results indicate a positive relationship between certified seed production in proximity to farm households and farm-level improved variety use, yields, and output, although this effect is diminishing at the margin. We report results on a crop-by-crop basis below and highlight the significance and magnitudes of these relationships, with details provided in Table 3 through Table 5.

For maize, results indicate that an increase in local certified seed production is associated with a statistically significant increase in yields. An increase in local certified seed production by 0.1 standard deviations from zero predicts a 4.65 percentage point increase in the likelihood of certified seed use, although the rate of increase declines as certified seed production expands (Table 3, Column c). The effect on self-reported use of certified seed exhibits similar patterns: an increase in local certified seed production by 0.1 standard deviations from zero predicts a 3.09 percent increase in yield (Table 3, Column g). However, the coefficient for the squared term of certified seed is statistically significant and negative, indicating diminishing yield returns to the expansion in certified seed production. In general, similar patterns emerge when we control for certified seed production in the LGA instead of in the state. For maize yields, the use of improved maize seed and certified maize seed, and production of certified maize seed by seed companies located in the same LGAs as respondents are positively related, but at declining rates as indicated by the statistically significant negative squared terms.

Table 3. Maize: Effects of one-standard deviation change

Categories	Use improved varieties (yes = 1)		Use of certified seeds (yes = 1)		Use of certified seeds (improved) (yes = 1)		Yield (proportional increase)	
	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Certified seed production (States of seed companies)	-0.178 (0.149)		0.465*** (0.170)		-0.020 (0.295)		0.309*** (0.103)	
Squared	0.175 (0.117)		-0.236* (0.127)		0.134 (0.199)		-0.149 (0.091)	
Certified seed production (LGA of seed companies)		1.040*** (0.137)		0.712*** (0.144)		0.547*** (0.183)		0.109 (0.068)
Squared		-0.804*** (0.116)		-0.594*** (0.112)		-0.415*** (0.141)		-0.121*** (0.037)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wave dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Intercept	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Samples responding at least two rounds	650	650	650	650	650	650	1945	1945
p-value (H0: model is insignificant)	.000	.000	.000	.000	.000	.000	.000	.000

Source: Authors. ***1% **5% *10%

Note: Standard errors (s.e.) are clustered at the level of enumeration area (EA), to account for potential serial correlation of idiosyncratic shocks at the EA level.

Table 4 shows similar patterns for rice: the effect on the likelihood of using certified seed is positive and non-linear. Specifically, increasing local production of certified rice seed by 0.1 standard deviations from zero predicts a 17.2 to 21.2 percentage point increase in the likelihood of certified rice seed use depending on whether certified seed production is measured at the state or LGA level (Table 4, Columns c, d). While the effects on yield and the use of improved varieties are not significant when controlling for state-level certified seed production, we observe positive but diminishing returns to yield when controlling for LGA-level certified rice seed production. The rates of these increases start declining as certified seed production expands, as indicated by the statistically significant negative squared terms.

Table 4. Rice: Effects of one-standard deviation change

Categories	Use improved varieties (yes = 1)		Use of certified seeds (yes = 1)		Use of certified seeds (improved) (yes = 1)		Yield (proportional increase)	
	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Certified seed production (States of seed companies)	-6.455 (7.050)		-0.442 (5.054)		2.123*** (0.985)		-0.217 (0.529)	
Squared	-6.713 (6.291)		3.401 (1.859)		-1.251*** (0.361)		0.261 (0.362)	
Certified seed production (LGA of seed companies)		0.565 (1.148)		-0.149 (0.752)		1.722** (0.657)		0.145** (0.066)
Squared		-0.489 (0.936)		-0.136 (0.686)		-1.147** (0.529)		-0.124** (0.059)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wave dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Intercept	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Samples responding at least two rounds	509	509	102	102	102	102	102	102
p-value (H0: model is insignificant)	.000	.000	.000	.000	.000	.000	.000	.000

Source: Authors. ***1% **5% *10%

Note: Standard errors (s.e.) are clustered at the level of enumeration area (EA), to account for potential serial correlation of idiosyncratic shocks at the EA level.

Cowpea exhibits similar patterns, which can be seen in Table 5. Increasing local production of cowpea-certified seed by 0.1 standard deviations from zero predicts a 4.6 to 8.9 percent increase in yield, depending on whether certified seed production is measured at the state or LGA level, with diminishing yield returns (Table 5, Columns a and g). LGA-level certified seed production also has a positive but non-linear effect on the self-reported use of certified cowpea seed.

Table 5. Cowpea: Effects of one-standard deviation change

Categories	Use improved varieties (yes = 1)		Use of certified seeds (yes = 1)		Use of certified seeds (improved) (yes = 1)		Yield (proportional increase)	
	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Certified seed production (States of seed companies)	0.890** (0.385)		0.612 (0.432)		0.646 (0.426)		0.464*** (0.128)	
Squared	-0.523** (0.204)		-0.288 (0.219)		-0.508** (0.201)		-0.438*** (0.107)	
Certified seed production (LGA of seed companies)		0.098 (1.116)		0.488*** (0.120)		0.029 (0.124)		0.013 (0.019)
Squared		-0.119 (0.114)		-0.511*** (0.120)		0.015 (0.124)		0.000 (0.015)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wave dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Intercept	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Samples responding at least two rounds	436	436	436	436	436	436	2076	2076
p-value (H0: model is insignificant)	.000	.000	.000	.000	.000	.000	.000	.000

Source: Authors. ***1% **5% *10%

Note: Standard errors (s.e.) are clustered at the level of enumeration area (EA), to account for potential serial correlation of idiosyncratic shocks at the EA level.

We use the case of cowpea to illustrate the estimated marginal effects of certified seed production by local seed companies on average yield, based on the results in Table 5, and evaluated at the sample means of all other covariates (Figure 3). The horizontal axis shows the certified seed production index which standardizes the variable S_{jt} on a range between 0 and1 (0 = minimum, 1 = maximum). We include index values up to about 0.6, beyond which few observations appear in our sample and the confidence interval widens. We observe that positive marginal effects of certified seed production on average cowpea yield gradually decline as local certified seeds production expands. Similar patterns are observed for maize and rice in our results, though with somewhat wider confidence intervals.

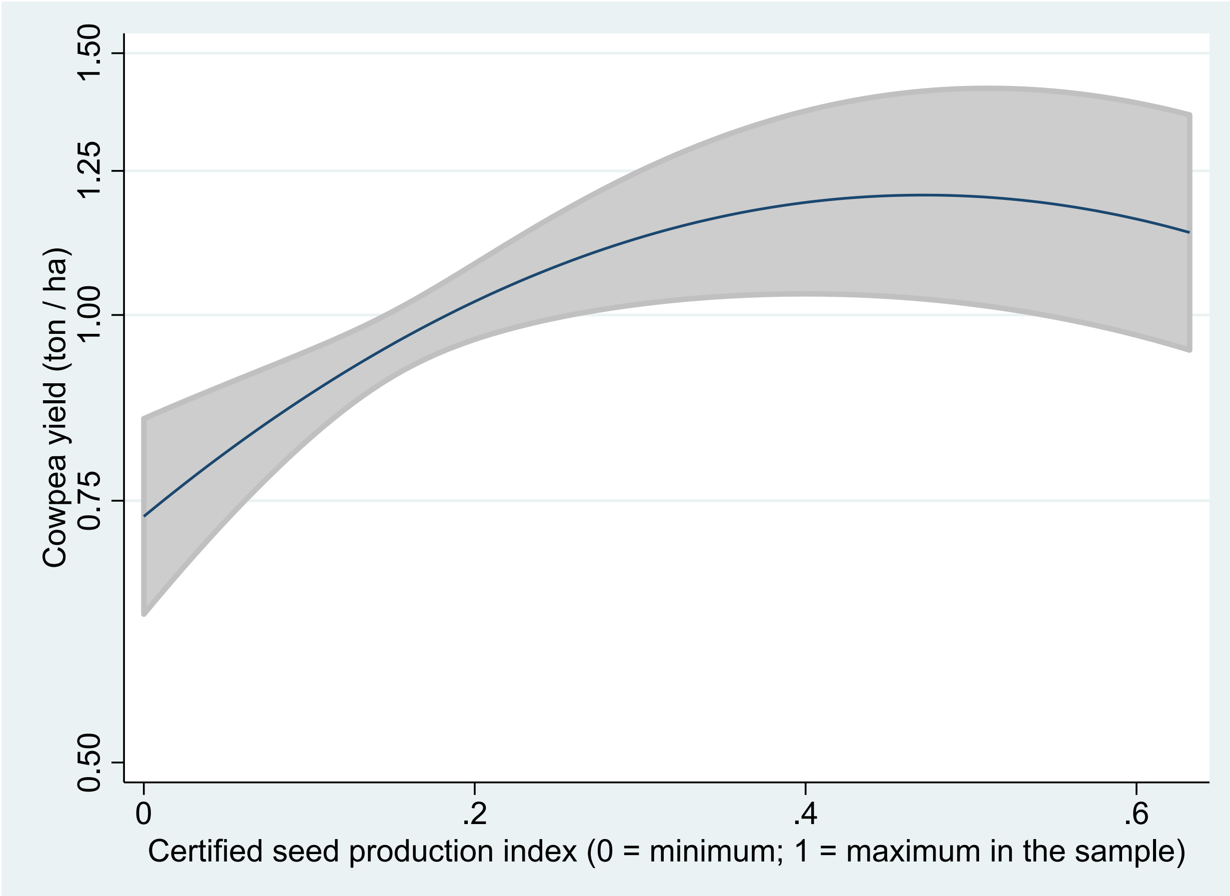


Figure 3. Effects of certified seed production on average yield (example of Cowpea)
Source: Authors.
Note: Shared area is 90% confidence interval.
The horizontal axis shows the certified seed production index which standardizes the variable S_{jt} on a 0 – 1 range (0 = minimum, 1 = maximum). We show up to the value of about 0.6 beyond which few observations appear, and confidence interval widens.

In sum, our findings are consistent with the hypothesis that while increasing certified seed production has positive effects on both yield and the use of improved or certified seeds for maize, rice, and cowpea, these effects may diminish at higher rates of certified seed production.

Potential drivers of non-linearity

Next, we explore the potential drivers of the non-linearities and heterogeneity observed in our results. These results come from pooling the data and crop fixed effects. Table 6 shows the estimated effects on the use of certified seed of time-variant factors (Z^*_{it}) in Equation (1), and time-invariant agroecological factors (Z_i) in Equation (2). Similarly, Table 7 shows the effects on yields of Z^*_{it} and Z_i as the source of heterogeneous effects of certified seed use C_{it}. Due to small sample sizes for cowpea and rice, we combine all crops in the regressions for Table 6 and Table 7, while adding crop fixed-effects.

Table 6. Determinants of certified seeds use (effects of one-standard deviation changes, all crops combined)

Determinants of certified seed use	Use of certified seeds = 1 if the respondent indicated so regardless of whether the respondent called them as "improved seeds" or "other seeds (traditional, local)"		Use of certified seeds = 1 if the respondent indicated so and only if the respondent called them as "improved seeds"	
	OLS-fixed effects model	Predicted time-invariant fixed effects of certified seed use	OLS-fixed effects model	Predicted time-invariant fixed effects of certified seed use
	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)
Soil alkalinity (pH)		1.131* (0.613)		0.636***(0.172)
Soil organic contents		-0.636* (0.393)		-0.439***(0.110)
Soil texture (medium)		-0.030 (0.487)		0.169 (0.137)
Soil texture (fine)		-2.584***(0.379)		0.027 (0.106)
Soil salinity		-0.022 (0.254)		0.000 (0.071)
Soil sodicity		0.476 (0.406)		0.342***(0.114)
Soil drainage (poor drainage)		2.298***(0.477)		0.337** (0.134)
Soil drainage (excess drainage)		-0.063 (0.282)		0.086 (0.079)
Rainfall (historical average)		-2.122***(0.776)		-2.107***(0.218)
Temperature (historical average)		-3.518***(0.819)		-0.948***(0.230)
Wind (historical average)		-0.977***(0.305)		-0.247***(0.086)
ln (farm size)	-0.026 (0.017)		0.010 (0.006)	
ln (agricultural capital)	0.078***(0.022)		-0.002 (0.007)	
ln (asset)	-0.115***(0.026)		0.058***(0.013)	
Female household head	-0.044 (0.036)		-0.014 (0.014)	
Geopolitical zone dummy	Yes		Yes	
Other control variables	Yes		Yes	
Certified seed production by seed companies in the state	Yes		Yes	
Intercept	Yes	Yes	Yes	Yes
Number of observations (panel samples growing the same crops in both waves)	920	920	920	920
p-value (H_0: model insignificant)	.000	.000	.000	.000

Source: Authors. ***1% **5% *10%

Note: Standard errors (s.e.) are clustered at the level of enumeration area (EA), to account for potential serial correlation of idiosyncratic shocks at the EA level.
Due to small samples for cowpea and rice, we combine all three crops in the regression, while adding crop dummy variables.

Table 7. Heterogeneous effects of certified seeds on yields (effects of one-standard deviation changes in interacted variables on the yield effects of certified seed use, all crops combined)

Determinants of yield	OLS-fixed effects model		OLS-fixed effects model		IV-fixed effects model	
	Coef.	(s.e.)	Coef.	(s.e.)	Coef.	(s.e.)
Used certified seed × Soil alkalinity	0.424*	(0.207)	0.289	(0.228)	0.900	(0.572)
× Organic contents	-0.342**	(0.149)	-0.361**	(0.172)	-1.476***	(0.507)
× Soil texture (medium)	0.096	(0.173)	0.013	(0.176)	0.268	(0.417)
× Soil texture (fine)	0.119	(0.123)	0.147	(0.134)	0.147	(0.323)
× Soil salinity	0.007	(0.114)	0.100	(0.110)	-0.155	(0.293)
× Soil sodicity	-0.046	(0.175)	-0.055	(0.182)	-0.050	(0.415)
×Soil drainage (poor drainage)	0.258*	(0.133)	0.269**	(0.127)	0.071	(0.288)
× Soil drainage (excess drainage)	0.185	(0.159)	-0.032	(0.180)	0.020	(0.421)
× Rainfall z-score	0.510	(0.322)	0.638*	(0.351)	-1.526*	(0.931)
× Temperature z-score	0.076	(0.129)	0.275**	(0.126)	-0.735**	(0.309)
× Wind	-0.018	(0.202)	0.299	(0.209)	-1.898***	(0.609)
× ln (farm size)	0.255**	(0.117)	0.264**	(0.121)	-0.263	(0.381)
× ln (agricultural capital)	0.261**	(0.119)	0.176	(0.118)	0.463	(0.338)
× ln (asset)	-0.074	(0.102)	-0.231**	(0.112)	-0.365	(0.287)
× Female household head	-0.129	(0.111)	-0.169	(0.123)	-0.617**	(0.270)
Used certified seed	Yes		Yes		Yes	
Used certified seed × maize	Yes		Yes		Yes	
Used certified seed × rice	Yes		Yes		Yes	
Geopolitical zone dummy	Yes		Yes		Yes	
Other control variables	Yes		Yes		Yes	
Certified seed production by seed companies in the state			Yes			
Number of observations (panel samples growing the same crops in both waves)	920		920		920	
p-value (H_0: model insignificant)	.000		.000		.000	
p-value (H_0: not overidentified)					.380	

Source: Authors. ***1% **5% *10%

Note: Standard errors (s.e.) are clustered at the level of enumeration area (EA), to account for potential serial correlation of idiosyncratic shocks at the EA level.

Table 6 shows that the use of certified seed is significantly affected by not only the quantity of certified seed produced by companies based in the state, but also various agroecological factors and socioeconomic characteristics. Specifically, certified seed use is generally higher in areas with higher soil alkalinity, lower soil organic contents, lower soil drainage property, less rainfall, less wind, and lower average temperatures within each geopolitical zone (controlled for by geopolitical zone dummies). While the effects of farm size and assets vary depending on how certified seed is defined, they also contribute to heterogeneity in the likelihood of using certified seed.

Table 7 shows that the effects of certified seed use on yield can vary depending on various agroecological and socioeconomic factors. We introduce an IV-fixed effects estimation given that the exogeneity of certified seed criterion is rejected, suggesting that OLS-fixed effects may be inconsistent. Results from the IV-fixed effects estimation suggest that the effects are greater in areas with higher soil alkalinity, lower soil organic contents, lower rainfall, lower average temperature, and less wind, as well as for male-headed households. These results suggest that the yield effects of certified seed use are more heterogeneous depending on agroecological conditions and the gender of the household head. Furthermore, the effects of various agroecological factors (soil alkalinity, soil organic contents, rainfall, temperature, and wind) are consistent with patterns of certified seed use in Table 6, suggesting that farmers are more likely to use certified seed in areas where the yield effects are greater as a result of these agroecological factors.

Unlike the heterogeneity in the effects of certified seeds shown above, evidence is limited regarding the heterogeneity of price differences between certified seeds and non-certified seeds even though significant heterogeneity in price differences can contribute to the non-linear effects of certified seeds reported in Table 3 through Table 5. Appendix Table 9 shows that, while certified seed prices are generally 25 to 40 percent higher than prices for non-certified seed, these differences are not statistically significantly affected by whether the farmers are located in LGAs or states where certified seed-producing companies are located.

In sum, the substantial patterns of agroecological and socioeconomic heterogeneity across locations in both yield effects and certified seed use effects may help to explain the observed non-linear patterns in Table 3 through Table 5. Intuitively, this may suggest that certified seed is used primarily by farmers who are able to realize relatively higher returns from certified seed use and are used less by farmers who are not.

Falsification tests

The robustness of our results in Table 3 through Table 5 can be assessed with a series of falsification tests, where we hypothesize that the effects of certified seed produced for other crops have a lower effect on our outcomes of interest. Table 10 through Table 12 in the Appendix summarize the results corresponding to Table 3 through Table 5. In general, the effects of certified seed of other crops are much less significant. Effects that are statistically significant are likely a result of the fact that certified seed production is somewhat correlated over time and space among these crops, as shown in Figure 2.

5 Conclusions

Despite the importance of seed quality to adoption and yield outcomes, there is relatively little evidence of either the benefits or drivers of certified seed use in developing-country agriculture. Using four waves of nationally representative household panel data from Nigeria, we assessed the relationship between spatial and temporal variations in the quantity of certified seed production and other agroecological and socioeconomic factors, on the one hand, and farm-level use and yields of certified maize, rice, and cowpea seed.

Our findings indicate that the availability of certified seed—captured by indicators of certified seed produced by seed companies headquartered in the states or LGAs of survey respondents—is associated with positive but declining marginal effects on use and crop yields. The yield effects of certified seeds are heterogeneous and depend on agroclimatic conditions and farmers' socioeconomic characteristics. The use of certified seeds is generally higher in areas with higher yield effects after controlling for certified seed production. These patterns lead to observed non-linearities in certified seed use because certified seed is more likely to be used by farmers with higher expected returns than farmers with lower expected returns. These results underscore the importance of considering the costs and returns to seed certification efforts carefully, especially when setting quantitative targets for certified seed production and uptake.

Since our analysis relies on fairly strong assumptions about the relationship between the location of seed company headquarters and the quantity of certified seeds available in those states, direct implications on seed quality assurance policies should be made with caution. Despite this limitation, our results are consistent with suggestions about the need for setting targets for certified seed production more carefully. Specifically, excessive expansion of certified seed production may not necessarily lead to higher use rates or yield outcomes when compared to more moderate levels of certified seed production. While the factors behind such results need to be investigated more carefully, they may be partly explained by potential tradeoffs with other forms of public support for agriculture, which compete with seed certification efforts for scarce public resources. This is particularly the case in countries like Nigeria, where limited seed certification capacity leads to significantly high marginal costs when trying to expand certified seed production.

We conclude the study by pointing out several areas for future research. First, to better assess the impact of seed quality assurance at the farm level, future studies should collect information on the supply of certified or other quality seeds at lower administrative levels where possible. We have used information about the states/LGAs in which the headquarters of seed companies are located, but that may not adequately capture the volume of certified seed available to farmers due to, for example, trade with other states/LGAs. Second, future analyses could be combined with better information on the potential heterogeneity in quality assurance systems and methods—information we have not analyzed in this study. Our study assumes that certified seed of each crop have undergone the same certification processes in terms of the rigor of inspections. Information on the heterogeneity of quality assurance systems and methods and how the supply of quality seed varies across locations can provide information about the potential role of alternative seed classes and standards such as Quality-Declared Seed (QDS). Third, information could also be combined with a more detailed assessment of costs involved with quality assurance to generate benefit-cost ratios for seed quality assurance and allow for comparisons with returns to other types of seed sector development interventions.

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Appendix

Table 8. Descriptive statistics of exogenous variables

Variables	Average (all 4 rounds)	Median (all 4 rounds)
Certified seeds produced (kg per capita in the state) (maize)	0.920	0.000
Certified seeds produced (kg per capita in the state) (rice)	1.196	0.000
Certified seeds produced (kg per capita in the state) (cowpea)	0.018	0.000
Household demographics		
Age of head (years)	52.329	51.000
Gender of head (female = 1)	0.139	0.000
male (0 – 14)	1.426	1.000
female (0 – 14)	1.282	1.000
male (15-60)	1.357	1.000
female (15-60)	1.582	1.000
male (61-)	0.234	0.000
female (61-)	0.161	0.000
Education of head (years)	4.787	5.000
Household asset (value per capita, 100)	1.943	0.671
Household received remittance (yes = 1)	0.045	0.000
Household has nonfarm income (yes = 1)	0.601	1.000
Farm size (purchased or distributed) (ha)	0.596	0.013
Number of farm plots (number)	2.094	2.000
Livestock asset value (value, 1,000)	1.951	0.139
Agricultural capital value (value, 100)	0.941	0.117
Fertilizer price (value)	1.018	0.980
Wage (male per day, value)	7.225	6.342
Access to extension (yes = 1)	0.136	0.000
Distance to administrative center (km)	74.521	57.800
Distance to market (km)	70.729	63.800
Community-level shocks: drought (yes = 1)	0.056	0.000
flood (yes = 1)	0.197	0.000
crop disease / pests (yes = 1)	0.105	0.000
livestock disease (yes = 1)	0.067	0.000
number of positive ones	0.547	0.000
number of other negative ones	0.403	0.000
Weather		
Annual rainfall (z-score)	1.026	1.109
Annual average temperature (z-score)	1.073	1.075
Annual rainfall, historical average 1980 – 2009 (mm)	1177.772	1073.909
Annual average temperature 1980 – 2009 (℃)	26.935	27.081
Annual average windspeed at 10m above ground (m / second)	2.518	2.311
Soil alkalinity (pH)	6.006	6.190
Soil organic content (g / kg of soil)	0.880	0.867
Soil texture – medium (proportion, 1 = 100%)	0.593	0.600
Soil texture – fine (proportion, 1 = 100%)	0.051	0.000
Soil salinity (deciSiemens per metre)	0.244	0.100
Soil sodicity (% of soil)	3.106	2.350
Soil with poor drainage (proportion, 1 = 100%)	0.229	0.100
Soil with excess drainage (proportion, 1 = 100%)	0.121	0.000

Source: Authors based on NBS & World Bank (2019).
Note: "Value" is equivalent to the value of kilogram of staple food evaluated at local market prices.

Table 9. Limited associations between seed price and the presence of certified-seed producing companies within the LGA

Variables	All crops combined		Maize	
	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)
Certified (yes = 1)	0.235*	0.317**	0.244	0.346*
	(0.126)	(0.143)	(0.169)	(0.204)
LGA with certified seed producing company (yes = 1)	-0.114	-0.126	-0.197	-0.225
	(0.121)	(0.122)	(0.194)	(0.198)
Certified * LGA with certified seed producing company	0.310	0.366	0.262	0.356
	(0.322)	(0.328)	(0.429)	(0.442)
State with certified seed producing company (yes = 1)	-0.246**	-0.221**	-0.550*	-0.570*
	(0.100)	(0.103)	(0.299)	(0.302)
Certified * State with certified seed producing company		-0.192		-0.260
		(0.192)		(0.304)
Improved varieties (yes = 1)	0.116	0.115	0.222	0.215
	(0.104)	(0.103)	(0.157)	(0.157)
Crop dummy	Yes	Yes		
LGA fixed effects	Yes	Yes	Yes	Yes
Year dummy (2015 / 2018)	Yes	Yes	Yes	Yes
Intercept	Yes	Yes	Yes	Yes
Number of observations	1,581	1,581	921	921
p-value (H_0: model insignificant)	.000	.000	.000	.000

Source: Authors. ***1% **5% *10%

Note: Standard errors (s.e.) are clustered at the level of enumeration area (EA), to account for potential serial correlation of idiosyncratic shocks at the EA level.

Table 10. Falsification for maize regression (Table 3)

Categories	Yield (proportional increase)		Use improved varieties (yes = 1)		Use of certified seeds (yes = 1)		Use of certified seeds (improved) (yes = 1)	
	Rice	Cowpea	Rice	Cowpea	Rice	Cowpea	Rice	Cowpea
	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)
Certified seed production (States of seed companies)	0.073 (0.153)	0.108 (0.156)	-0.076 (0.501)	-0.449 (0.413)	1.710*** (0.443)	0.834** (0.366)	-0.400 (0.535)	-0.543 (0.439)
Squared	0.055 (0.118)	-0.060 (0.119)	0.027 (0.295)	0.397 (0.262)	-0.845*** (0.261)	-0.251 (0.252)	0.421 (0.315)	0.600** (0.278)
Certified seed production (LGA of seed companies)	-0.068 (0.075)	0.159 (0.173)	-0.083 (0.146)	0.189 (0.213)	-0.154 (0.129)	-0.614*** (0.188)	-0.231 (0.156)	-0.356 (0.226)
Squared	0.017 (0.072)	-0.154 (0.169)	0.146 (0.111)	-0.288 (0.214)	0.183* (0.098)	0.465*** (0.190)	0.300** (0.119)	0.154 (0.228)

Source: Authors. ***1% **5% *10%

Note: Standard errors (s.e.) are clustered at the level of enumeration area (EA), to account for potential serial correlation of idiosyncratic shocks at the EA level.

Table 11. Falsification for rice regression (Table 4)

Categories	Yield (proportional increase)		Use improved varieties (yes = 1)		Use of certified seeds (yes = 1)		Use of certified seeds (improved) (yes = 1)	
	Maize	Cowpea	Maize	Cowpea	Maize	Cowpea	Maize	Cowpea
	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)
Certified seed production (States of seed companies)	1.024 (2.245)	-1.078 (2.904)	-13.560 (16.694)	-3.218 (1.967)	11.696 (9.527)	1.127 (1.122)	-0.400 (0.535)	-0.552 (2.359)
Squared	-1.803 (4.005)	0.464 (2.235)	-12.820 (7.820)	5.565 (3.259)	-5.526 (4.468)	-1.688 (1.860)	0.421 (0.315)	1.203 (3.910)
Certified seed production (LGA of seed companies)	-0.583 (1.337)	NA[a]	2.427 (11.292)	NA[a]	-0.154 (0.129)	NA[a]	-0.231 (0.156)	NA[a]
Squared	0.522 (1.212)	NA[a]	-0.981 (9.542)	NA[a]	0.183* (0.098)	NA[a]	0.300** (0.119)	NA[a]

Source: Authors. ***1% **5% *10%

Note: Standard errors (s.e.) are clustered at the level of enumeration area (EA), to account for potential serial correlation of idiosyncratic shocks at the EA level.

[a]Certified seed production in LGA (based on LGA of seed companies) for cowpea is all 0 for LGAs where rice producer observations are available.

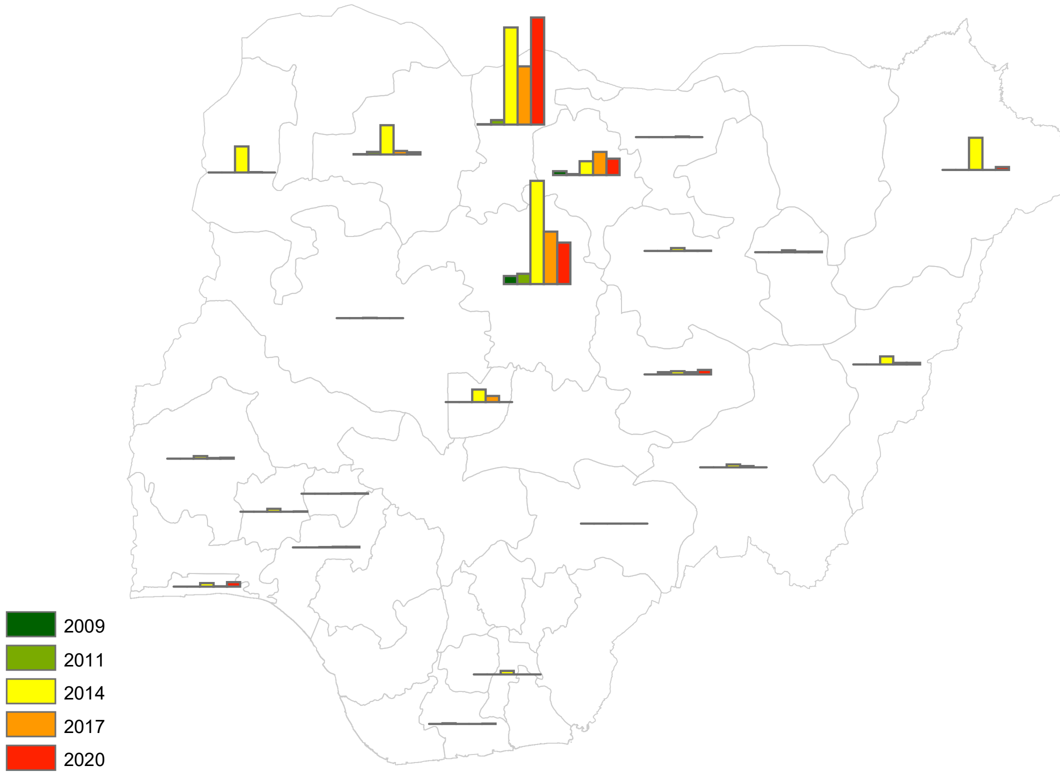
Table 12. Falsification for cowpea regression (Table 5)

Categories	Yield (proportional increase)		Use improved varieties (yes = 1)		Use of certified seeds (yes = 1)		Use of certified seeds (improved) (yes = 1)	
	Maize	Rice	Maize	Rice	Maize	Rice	Maize	Rice
	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)	Coef. (s.e)
Certified seed production (States of seed companies)	0.527 (0.874)	-0.095 (0.078)	-0.205 (0.332)	0.839*** (0.314)	-0.786 (2.339)	0.265 (0.265)	0.881 (3.096)	0.265 (0.302)
Squared	-0.847 (1.316)	0.130* (0.077)	0.106 (0.158)	-1.389*** (0.477)	0.889 (1.114)	-0.008 (0.402)	-0.137 (1.475)	-0.378 (0.278)
Certified seed production (LGA of seed companies)	-0.074 (0.102)	-0.133 (0.099)	0.894 (3.875)	-0.301 (0.409)	-3.140 (2.730)	-0.471 (0.345)	3.608 (3.614)	-0.196 (0.393)
Squared	0.081 (0.094)	0.110 (0.096)	-3.289 (14.661)	0.110 (0.588)	1.067 (1.033)	0.347 (0.496)	-1.421 (1.367)	0.297 (0.565)

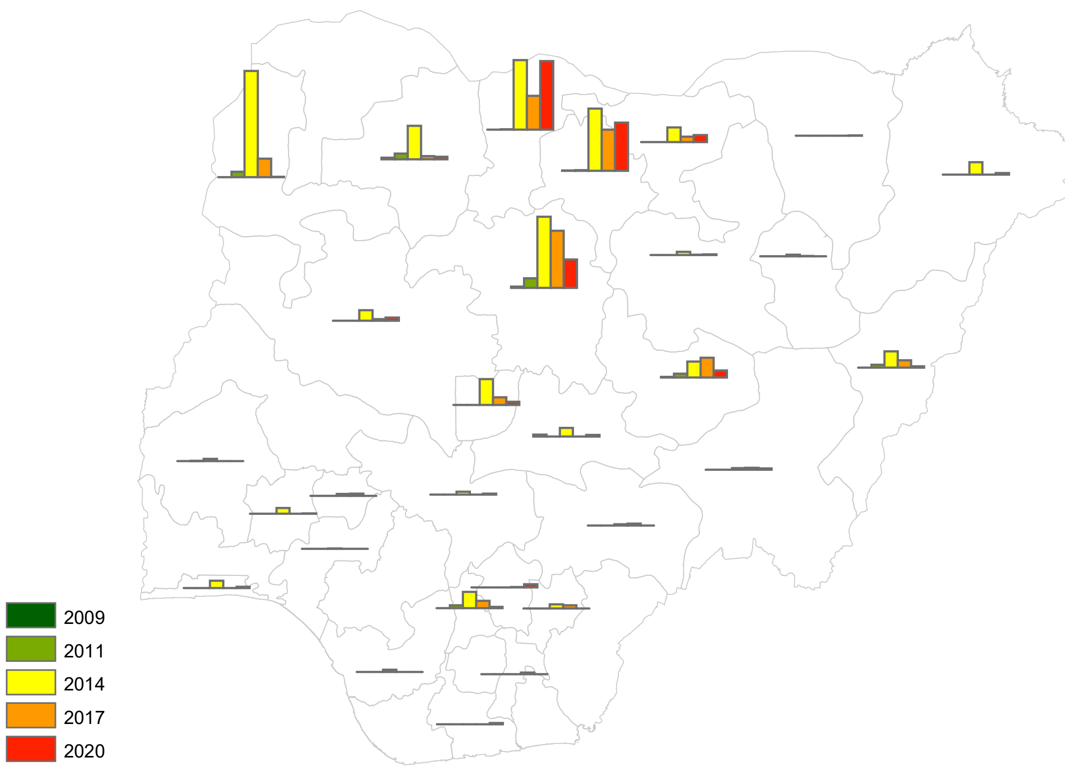
Source: Authors. ***1% **5% *10%

Note: Standard errors (s.e.) are clustered at the level of enumeration area (EA), to account for potential serial correlation of idiosyncratic shocks at the EA level.

Maize



Rice



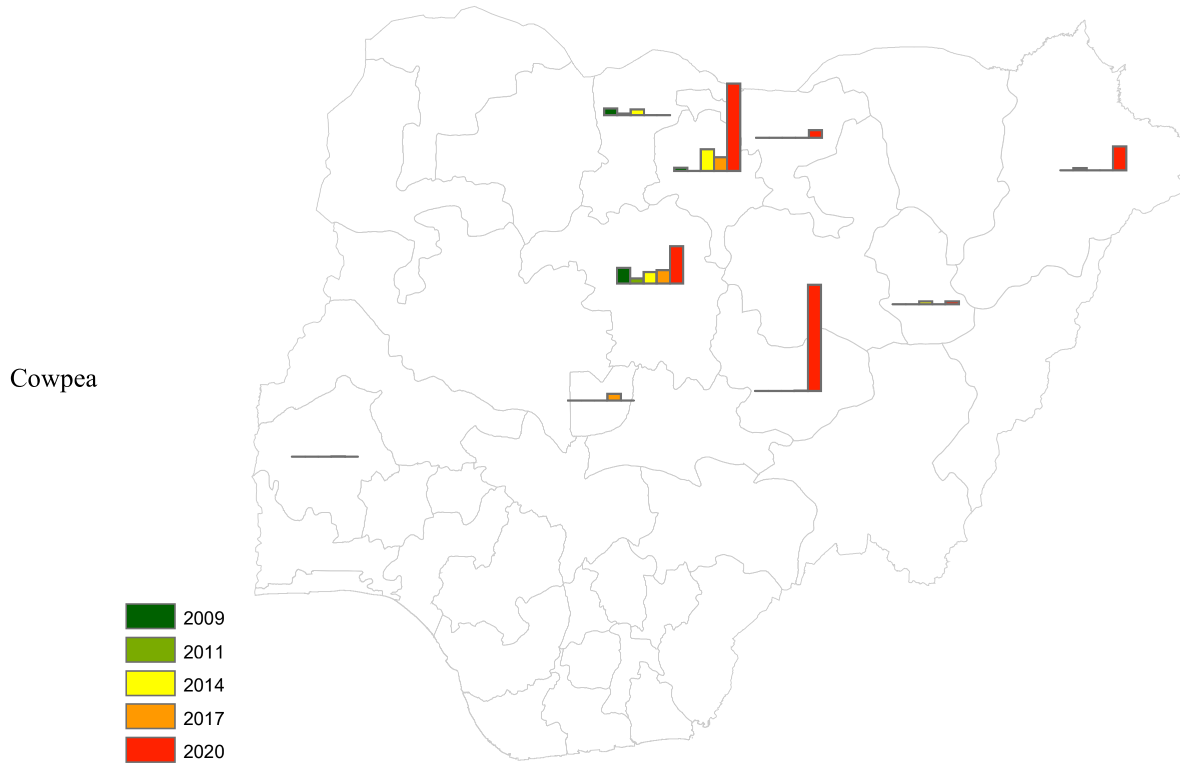


Figure 4. Locations of states and certified seed produced by seed companies located in the states

Source: Figure 2.

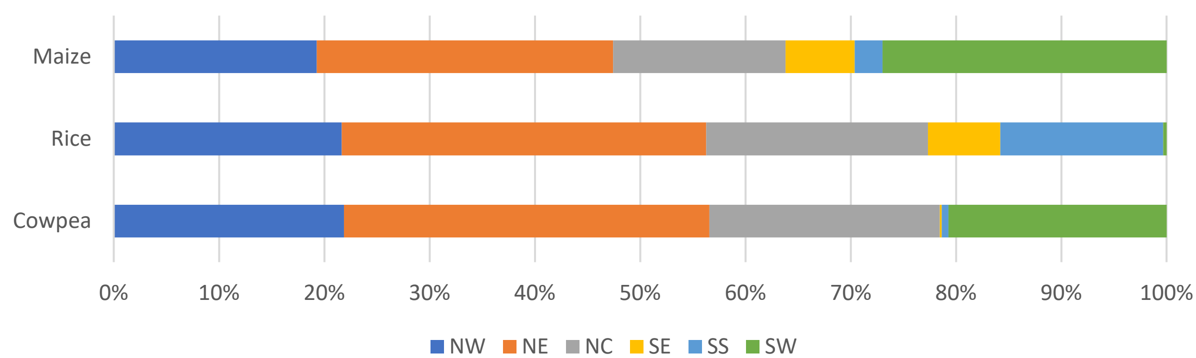


Figure 5. Share (%) of seed use by geopolitical zones (average across LSMS 2010, 2012, 2015, 2018).

Source: Authors based on LSMS-ISA. NW = Northwest; NE = Northeast; NC = North Central; SE = Southeast; SS = South South; SW = Southwest.

Note: Figures are based on the quantity of seed planted in each plot reported in LSMS-ISA data.

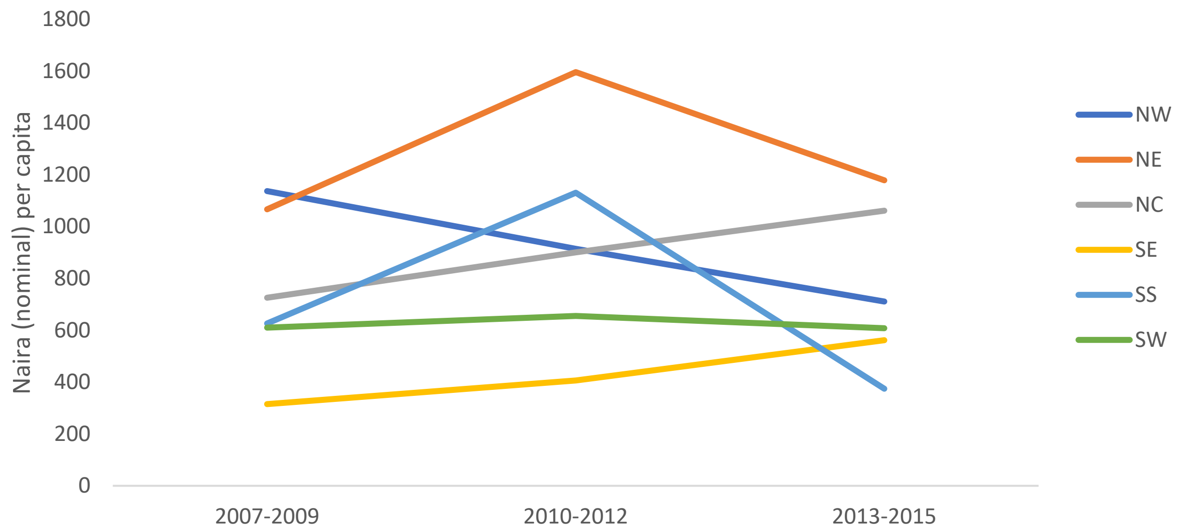


Figure 6. Per capita annual public expenditures on agriculture by Geopolitical zones (3-year averages)

Source: Authors based on Takeshima et al. (2022). NW = Northwest; NE = Northeast; NC = North Central; SE = Southeast; SS = South South; SW = Southwest

Note: Figures are sum of State and LGA-level public expenditures in the agricultural sector (Takeshima et al. 2022).

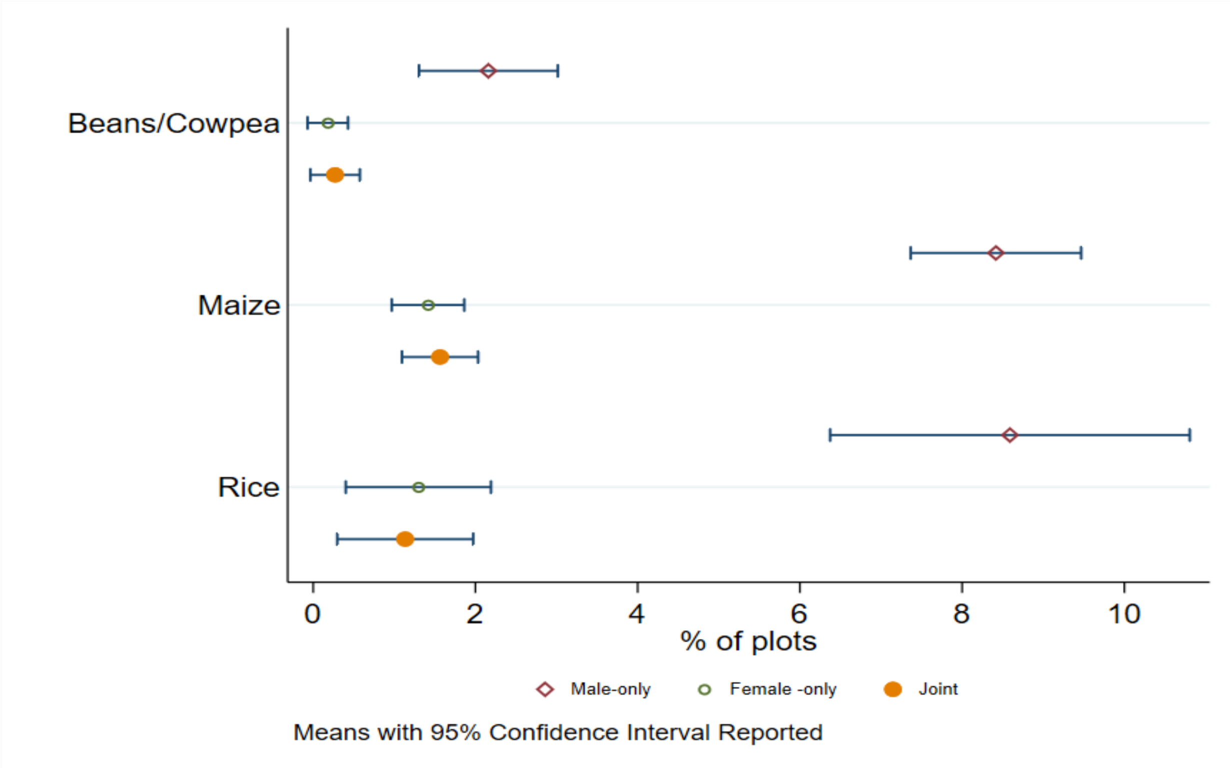


Figure 7. Self-reported use of improved varieties by sex of plot manager and crop
Source: Authors based on LSMS-ISA data.

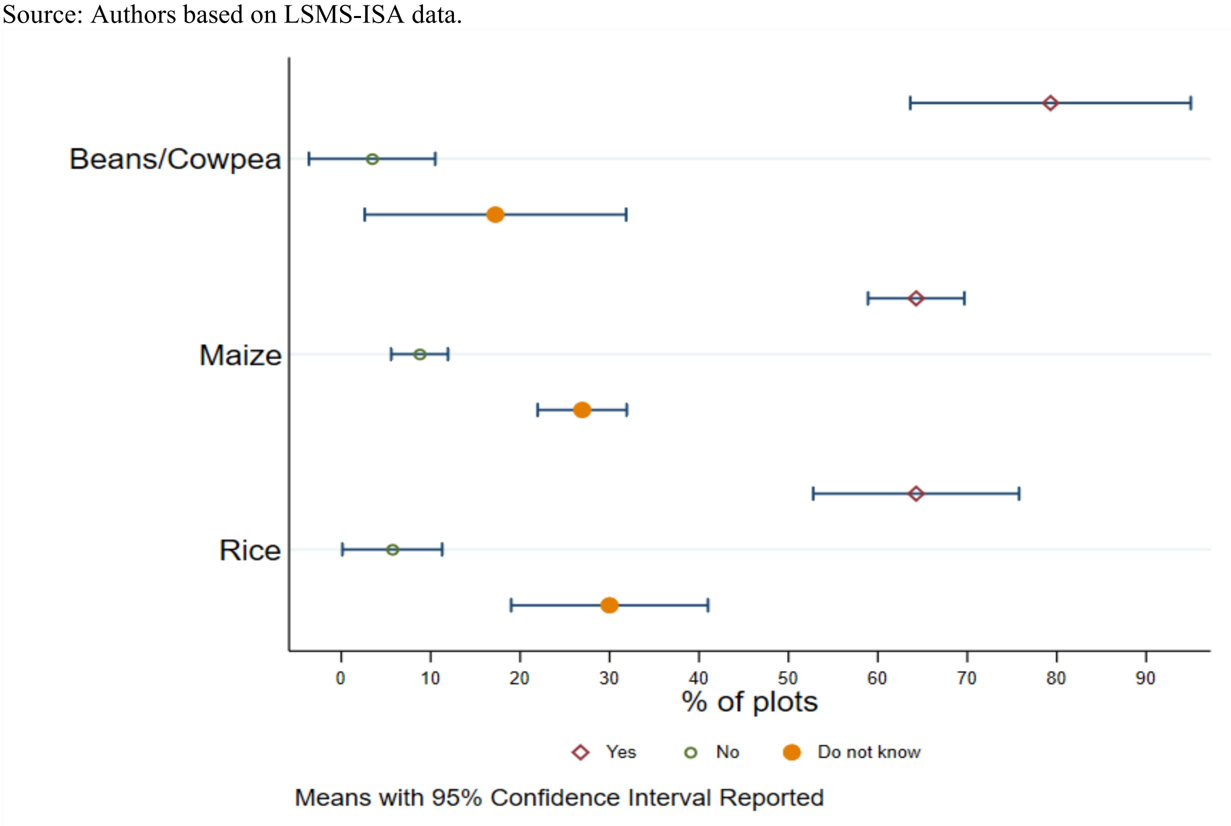
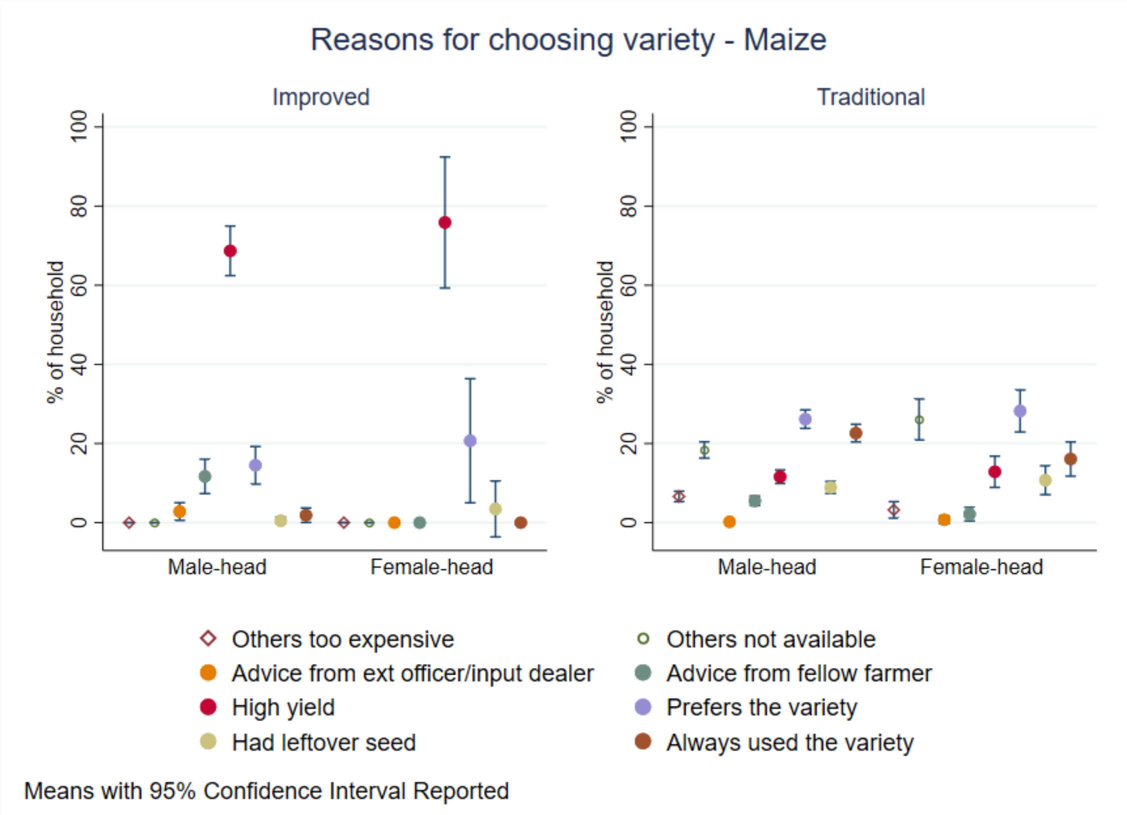
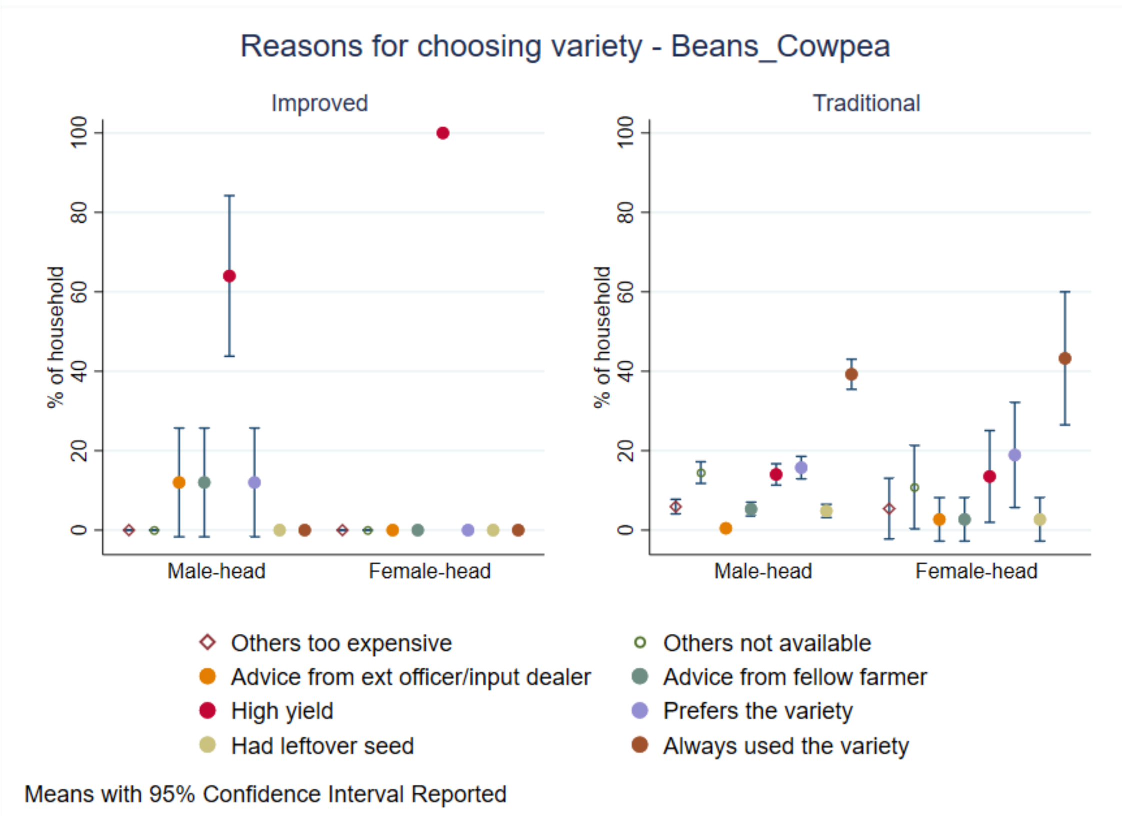


Figure 8. Self-reported certification status of improved varieties by plot manager and crop
Source: Authors based on LSMS-ISA data.


Reasons for choosing variety - Maize
Improved
Traditional
% of household
0
20
40
60
80
100
Male-head
Female-head
Others too expensive
Others not available
Advice from ext officer/input dealer
Advice from fellow farmer
High yield
Prefers the variety
Had leftover seed
Always used the variety
Means with 95% Confidence Interval Reported


Reasons for choosing variety - Beans_Cowpea
Improved
Traditional
% of household
0
20
40
60
80
100
Male-head
Female-head
Others too expensive
Others not available
Advice from ext officer/input dealer
Advice from fellow farmer
High yield
Prefers the variety
Had leftover seed
Always used the variety
Means with 95% Confidence Interval Reported

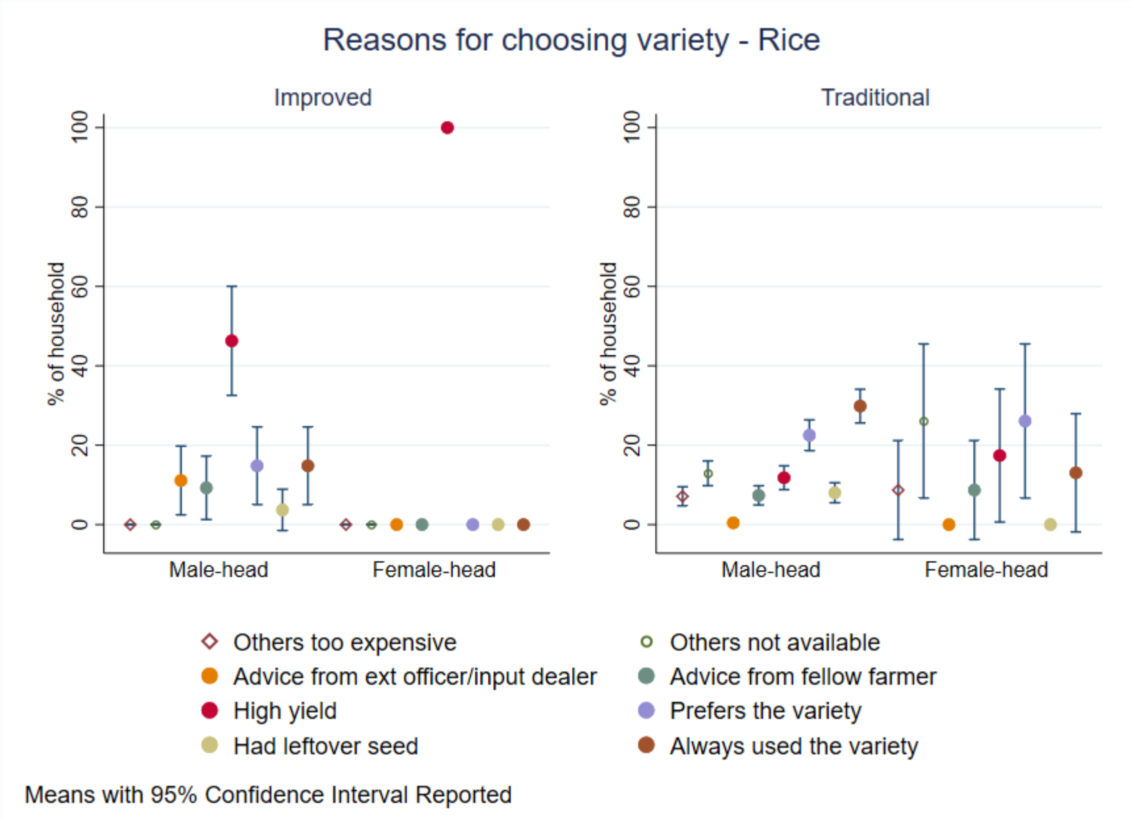


Figure 9. Reasons for choosing varieties of maize, rice and cowpea/beans
Source: Authors based on LSMS-ISA.

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