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How responsive is Nigeria's cassava seed system to farmers' demand? Exploring supply and demand interactions in three farming communities

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ABSTRACT

Based on a concept for demand-orientation in seed systems, we characterized Nigeria's cassava (*Manihot esculenta*) seed system from national to local level and farmers' demand in three study sites. Interviews with seed-system actors explained their roles for supply-side functions. Focus group discussions and a survey described multiple aspects of farmers' demand. Our findings show that the national agriculture development program alone did not have the capacity to supply farmers with sufficient seed of desired varieties. Seed exchange between farmers and informal seed sellers contributed to the distribution of seed and new varieties. The presence of seed sellers and farmers' demand for cassava seed varied between the three study sites, farmer types and gender. We conclude that informal seed sellers and village seed entrepreneurs have a potential to respond to farmers' heterogeneous demands. However, without recurrent demand for specialized seed production or continuous support from the formal system, they do not reach underserved markets.

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Cassava; demand-orientation; Nigeria; seed system; planting material

Introduction

Using better varieties and higher quality seed[1] in farmers' fields is one pathway to enhance agricultural productivity and the quality of food. Root, tuber, and banana (RT&B) crops make a particular case. As some of the most important staple crops in the world's poorest regions, they play an important role in food security in the global South (RTB 2021). Because of their vegetative propagation via stems, roots, tubers, or suckers, their seed is managed differently from "true"

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seed crops. High potential for re-use by farmers, low profitability margins, bulkiness in handling and transport, and quick perishability of the planting material make them unattractive for commercial breeding and private sector seed programs (Bentley et al. 2018; Almekinders et al. 2019). International crop improvement programs, in collaboration with national agricultural research institutes, in many African countries, have contributed to breeding, release and spread of improved varieties and distribution schemes for clean planting material of an improved physiological quality. These efforts were informed by research on farmers' varietal preferences and aimed to provide farmers with better adapted and more nutritious varieties (Alene et al. 2015). Despite large investments across several decades, the public sector has not been able to meet the expected rates of varietal adoption, turnover and use of quality seed in RT&B crops (Walker and Alwang 2015; Spielman and Smale 2017).

There is a range of reasons why the supply of improved varieties and quality seed of RT&B crops do not meet farmers' demand and the uptake remains limited, and they vary across crops and context. Two recent studies presented further explanation. Thiele et al. (2020) analyzed cases of multiple RT&B crops in Africa and concluded that varietal change was limited because of insufficient priority given to consumer-preferred traits by breeding programs. The authors indicated that more research was needed to understand the impact of gender differences in consumption preferences and the extent to which informal seed systems contributed to the slow uptake. McEwan et al. (2021) presented findings from an interdisciplinary group of CGIAR scientists on seed systems. The authors identified four major gaps in seed system research, which included understanding farmers' demand and their seed acquisition behavior, identifying effective seed delivery channels, ensuring seed health, and identifying effective policies and regulations. The indicated knowledge gaps in seed system research of both studies call for a better understanding of the demand side as well as the supply side to design seed system interventions that make better adapted seed available to different types of farmers.

The supply side of RT&B seed systems is often characterized by a large variability of formal and informal actors and dynamic interactions among them. While breeding programs, seed certification schemes and early generation seed production are mostly operated by the public sector, informal seed traders often play a central role in seed delivery to farmers (Sperling et al. 2020b). A similarly important contribution to the supply of improved germplasm are farmer seed networks (Coomes 2010; Coomes et al. 2015). Because of the largely informal trade, sharing and re-use of RT&B seed, farmers' demand for seed cannot easily be measured by plotting a demand curve of certain varieties and types of seed. Studying farmers' demand

requires an approach that goes beyond the economic concept of demand and includes also not clearly defined needs of farmers (Pircher and Almekinders 2021).

Understanding to what extent seed systems are able to respond to different types of farmers' demand, requires not only an analysis of demand and supply but also the mutual shaping of both sides. Literature that addresses both the supply side and demand side of RT&B seed systems consists of few empirical studies only (Nangoti, Kayobyo, and Rees 2004; Gildemacher et al. 2009; Adam, Badstue, and Sindi 2018; Bentley et al. 2018; Almekinders et al. 2019). Some of these studies analyzed the role of various seed system actors and to what extent farmers' demand was met in these seed systems. However, in none of these studies the supply-demand interactions were presented in sufficient detail to draw conclusions about the underlying dynamics in demand and supply that make seed systems responsive to farmers' demand. To address this knowledge gap, we carried out a study on the cassava (*Manihot esculenta*) seed system in Nigeria.

Nigeria's cassava seed system has been influenced by large-scale interventions from research and development in breeding, seed multiplication and distribution in the past 50 years (Alene et al. 2015; Oparinde et al. 2016). Despite these efforts, most farmers sourced seed from friends, relatives and neighbors, and informal stem trade remained a common form of seed acquisition (Almekinders, Pircher, and Obisesan 2017; Wossen et al. 2017). Yet, the informal sector is not considered very effective or efficient; the cassava seed system needs to better address farmers' demand for varietal traits and improve distribution schemes to reach farmers better (Bentley et al. 2017). Therefore, the objective of our study was to characterize the functioning of the seed system from a national to a local level as well as different aspects of farmers' demand. The following questions guided our research: Who are key actors across key functions of the cassava seed system? How do these actors interact to make adapted seed available and accessible to farmers? What demands for cassava seed do farmers have? How are these demands addressed by the supply side of the system?

Conceptual framework to study demand and supply in seed systems

In our analysis, we consider farmers' demand for seed as an outcome of the interplay between demand and supply-side in a co-evolutionary process (Dijk and Yarime 2010; Saviotti and Pyka 2013). To capture the mutual influence between both sides of this interplay, we build on analytical dualism between agency and structure (Archer 1995). Farmers' choices and decision making for farming technologies, such as seed, can be explained by behavioral factors

that are shaped largely by agency (Crane, Roncoli, and Hoogenboom 2011; Dessart, Barreiro-Hurlé, and Van Bavel 2019). To describe farmers' demand, i.e., their preferences for specific varieties and types of seed, we take into account the various aspects of demand that were conceptualized in (Pircher and Almekinders 2021): (i) varietal traits, (ii) quality of seed, (iii) seed sourcing, and (iv) quantity of seed. These preferences and choices are not only driven by farmers' agency alone, but influenced by structures that are also described as systems, regimes or rules of the game (Geels 2004). We studied these structures with a systems approach. The use of systems concepts for analysis, and thus their explanatory power, varies strongly with different perspectives for systems thinking that have evolved across time (Ison 2017; Reynolds and Howell 2010). In agricultural innovation systems, there are three different strands of thinking on how a system can be interpreted: an infrastructural view, a process view, and a functionalist view (Klerkx et al. 2012). In this study, we are taking a functionalist systems perspective, which explains the overall functioning of a system by the functioning of sub-systems and their interactions.

Seed systems can operate on different geographical scales and levels (e.g., local, national, international) (Almekinders, Louwaars, and de Bruijn 1994), consist of formal and informal sectors (McGuire and Sperling 2016), and other interacting sub-systems like project-based seed systems (Gibson 2013; Rachkara et al. 2017). Drawing upon the work of Checkland (1981) and Banathy (1997), Christinck et al. (2018a) conceptualized seed systems as human activity systems, which are established and maintained by human actors. They highlight that human activity systems can be defined at three levels: *(1) the collective purpose it serves; (2) the individual purposes of its members; and (3) the relations with and contributions to the larger environment, in which it is embedded*. While the various actors in the system have individual goals (e.g., creating profit with seed trade), the collective purpose of a seed system is to ensure that sufficient seed (in quality and quantity) that farmers and their market partners require is available at the right time and place at an affordable price (Christinck et al. 2018a).

In our model of a seed system, we consider the following functions that lead to the collective purpose: (i) provision of a legal framework, (ii) variety development, (iii) seed multiplication, (iv) seed dissemination and exchange, and (v) crop production and use (adapted from Christinck et al. 2018b). Seed system actors carry out activities that contribute to these functions, thus to the collective purpose. The boundaries of seed systems are surrounded by a "larger environment" that includes agroecological conditions, genetic resources, markets for produce, as well as a political and a socio-cultural context for farming. This environment can change across time and

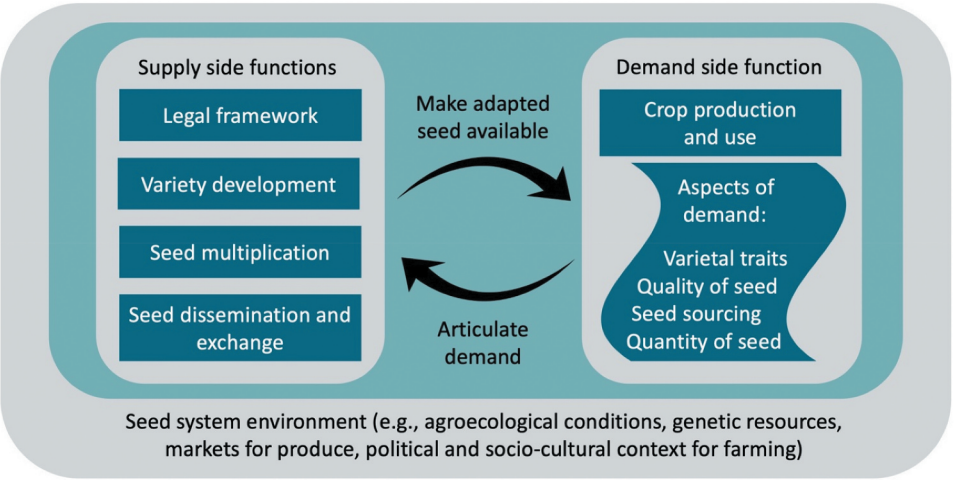

Figure 1. Model to study supply, demand and its interactions in RT&B seed systems (based on five seed system functions by Christinck et al. (2018b)).

dynamically influence the goals and activities of actors, and their interactions in the system (Christinck et al. 2018b).

A well-functioning seed system provides farmers with seed that is free of diseases, helps them adapt to local and global challenges, such as climate change, and creates enabling conditions for disadvantaged social groups, such as women, youth and ethnic minorities (Andrade-Piedra et al. 2020). To address these diverse needs of farmers better, researchers have emphasized the importance of demand-orientation in seed systems and outlined strategies for demand-driven breeding and seed system development (Ceccarelli and Grando 2007; Witcombe and Yadavendra 2014; Rubyogo et al. 2016; CGIAR 2020). Following these perspectives, we consider demand-driven seed systems as systems in which farmers' demand interacts with the supply side of seed systems in two ways. Firstly, the supply side of the seed system aims to provide seed that meets farmers' demand. Secondly, the articulation of farmers' demand acts as a driver for the supply side of the seed system. This could be through farmers' feedback in the breeding process with participatory plant breeding and variety selection schemes (e.g., Almekinders and Elings 2001; Sperling et al. 2001; Ceccarelli and Grando 2007). As such, providing the "right" seed to farmers is not only a static outcome but part of a process that consists of a dynamic interplay between demand and supply in a system (see Figure 1).

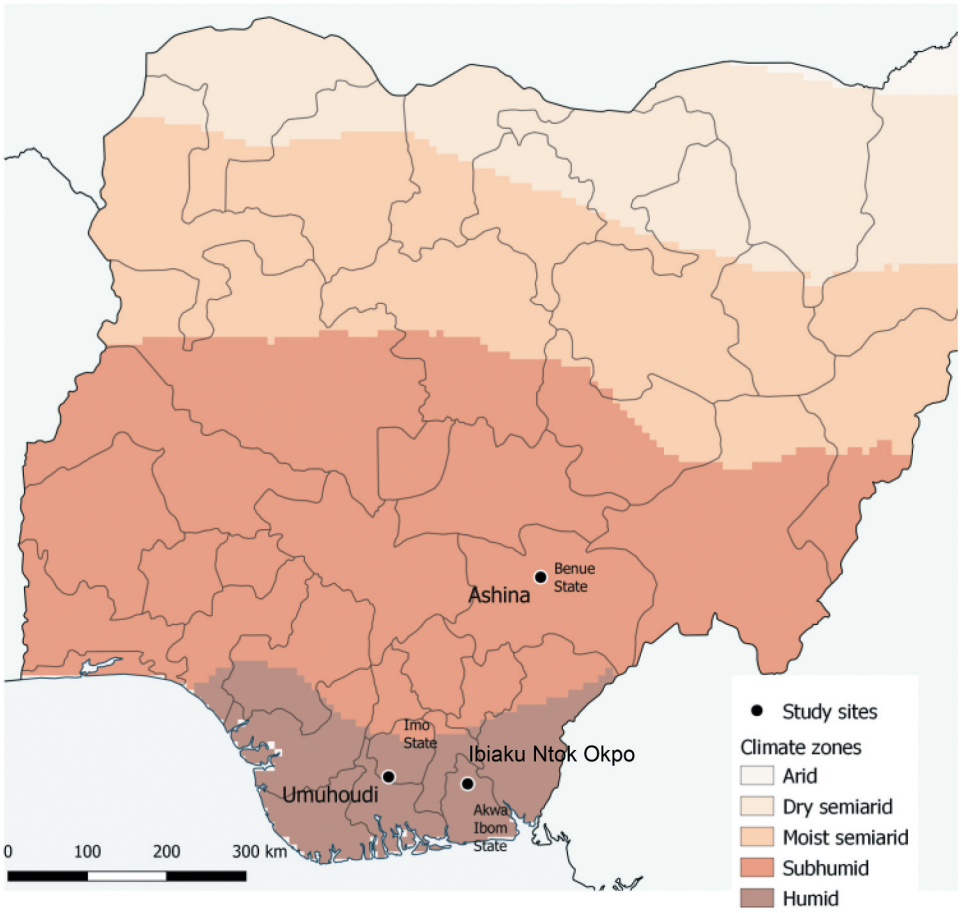

Figure 2. Map of Nigeria's agro-ecological zones with three study sites. (Produced with QGIS 3.4 using GIS data from HarvestChoice, 2015.).

Materials and methods

Description of the study sites

To present some cases that show a variation in the functioning of cassava seed systems in Nigeria, we selected three study sites that represent three major different cultural and agro-ecological zones (see Figure 2): Umuohuodi (Umuapu Ohaji/Egbema local government area [LGA], Imo State, South East Zone); Ibiaku Ntok Okpo[2] (Ikono LGA, Akwa Ibom State, South-South Zone); and Ashina (Gwer East LGA, Benue State, North Central Zone). The criteria for site selection were the presence of small to large farms and areas where cassava was a major crop in farming systems. Below, we describe the three study sites, which build the agro-ecological, socio-cultural, market and policy environment of the selected cassava seed systems on a local level.

In **Ibiaku Ntok Okpo** (located in Akwa Ibom State), the vegetation is predominantly lowland rainforest. The most important food crops are cassava, yam (*Dioscorea rotundata*), maize (*Zea mays*), rice (*Oryza sativa*), and cocoyam (*Colocasia esculenta*). The growing season for cassava corresponds with the rainy season (March–October). Cassava roots are processed into *gari* (granular flour made by roasting fermented cassava) and *fufu* (fermented wet cassava paste) for home consumption; local markets exist for gari and raw cassava roots. Land fragmentation results in relatively small farm sizes compared with the other study sites and are seen as a challenge to cassava farming. In **Umuohuodi** (located in Imo State), the vegetation is humid tropical rainforest. Cassava is the most important staple crop next to plantain and banana (*Musa* spp.). It is typically grown in the rainy season (March/April–October) and processed into *gari, fufu* and *tapioca* (a form of processed root for starch production) for home consumption and sale to traders on the nearby market. Large areas of land are available and mostly communally owned. Personally owned lands exist to a limited extent and are used for cassava cultivation, too.

Ashina (located in Benue State) is situated in the savannah zone with a considerably shorter growing season (May–October), followed by six months of dry season. The long dry season makes it more difficult for farmers to keep cassava stems in good condition for the next planting period. The farmers in the community own relatively large areas of land (up to 15 ha), which they cultivate with cassava, soybean (*Glycine max*), sorghum (*Sorghum bicolor*), rice, yam, groundnut (*Arachis hypogaea*), and vegetables like pepper (*Capsicum annuum*) and okra (*Abelmoschus esculentus*), and fruit trees (e.g., *Citrus*). Cassava and soybean are considered main crops. Roots are predominantly processed into *akpu* and *gari* for home consumption and sale on the market. The markets in Ashina and around are more active and better accessible than in the other two study sites.

Methods for data collection and analysis, and sampling

Expert discussions in workshops and meetings provided first insights into the Nigerian cassava seed system as a whole and helped to design an adapted study approach. The next steps of data collection were identifying actors, activities and interactions in performing seed system functions, and understanding the variations and dynamics of demand between and within study sites. A study team, supported by enumerators and translators, collected data for two studies: the first study was on farmers' demand for seed (from August until December 2017) and the second study was on the actors, activities and interactions in the seed system (from May 2018 until

June 2018). Both studies applied the principles of a small N/exploratory case study method that has been described as one tool for seed system diagnosis as part of a toolbox for working with RT&B seed systems (Andrade-Piedra et al. 2020). Small N/exploratory case studies combine quantitative and qualitative data, and are more oriented toward exploring *real-world* diversity and similarity in a cross-case analysis than toward statistically significant differences and correlations (Mahoney 2000; Ebbinghaus 2005). The explanatory power of this method lies in a cross-case comparison (in combination with within-case studies) of purposefully selected groups of farmers and other seed system actors and the different communities.

The study on farmers' demand for cassava seed (first study) was based on focus group discussions (FGDs) with farmers from three farming communities, individual interviews with farmers in the same study sites, and expert workshop discussions. All farmers were informed about the purpose of the discussions and interviews and were asked if they agreed that the information could be used for scientific reports. No other personal data were recorded but the name of the farmer, gender, age and community where he or she was living.

To capture the range of different types of farmers in the study area, we held two FGDs with farmers from Imo State and Benue State on how they would differentiate cassava farmers in their communities. Based on these discussions, we defined three categories of cassava farmers: *small* (size of cassava fields < 0.5 ha), *medium* (size of cassava fields 0.5–2 ha), and *large* (size of cassava fields > 2 ha). A preliminary data collection in the three study sites in October 2017 with gender-balanced FGDs served as an entry point to the communities and helped to explore the local context of farming and growing cassava. Subsequently, we carried out a survey based on farming households that reflected all defined farmer categories via purposeful

Table 1. Number of interviewed farmers in individual interviews and number of focus group discussions (FGDs) in the three study sites carried out for the study on farmers' demand.

	Respondents of individual interviews			
Study site	*Small farmers*	*Medium farmers*	*Large farmers*	FGD participants
Ibiaku Ntok Okpo (South-South Zone); first study phase	5 (1 male/4 females)	5 (3 males/2 females)	5 (5 males/0 female)	23 (10 males/13 females), 12 (7 males/5 females)
Ibiaku Ntok Okpo (South-South Zone); second study phase	5 (1 male/4 females)	6 (5 males/1 female)	4 (3 males/ 1 female)	10 (9 males/1 female)
Umuohuodi (South East Zone); first study phase	5 (2 males/ 3 females)	8 (5 males/3 females)	3 (1 male/2 females)	28 (10 males/18 females), 13 (5 males/8 females)
Umuohuodi (South East Zone); second study phase	4 (2 males/ 2 females)	6 (2 males/4 females)	4 (2 males/2 females)	11 (5 males/6 females)
Ashina (North Central Zone)	9 (7 males/ 2 females)	26 (20 males/ 6 females)	12 (6 males/ 6 females)	10 (5 males/5 females), 16 (12 males/4 females)

sampling (see Table 1). The survey contained questions on a household level and was administered to both women and men (40% and 60%, respectively), who were mobilized by leaders and resource persons in the three study communities. The findings were discussed in a workshop with experts from the National Root Crop Research Institute (NRCRI) and partner organizations of the project "Building an Economically Sustainable, Integrated Seed System for Cassava in Nigeria" (BASICS). The discussions helped to verify the findings and to refine the survey questionnaire. The interviews with farmers, based on the refined questionnaires, took place in the second study phase from November to December 2017.

The study on actors, activities and interactions in the seed system (second study) was based on individual interviews of key experts from formal institutions and informal seed sellers in the cassava seed system, and discussions of a final workshop. We conducted eight interviews with key informants from NRCRI, the Agriculture Development Program (ADP), the National Agricultural Seed Council (NASC), the International Institute of Tropical Agriculture (IITA), the BASICS project, and HarvestPlus on their mandate, strategy and seed distribution channels. These institutions and projects were identified as important actors in the cassava seed system in an earlier workshop (see above). In each of the three study sites, we interviewed seed sellers, which we identified through collaborating cassava farmers (Akwa Ibom State: 6 women/6 men, Benue State: 6 women/8 men, Imo State: 4 women/8 men). Because markets had been identified as important dissemination channels for cassava stems, we additionally visited six community markets in Ibiaku Ntok Okpo, five in Umuohuodi, and two in Ashina. When seed sellers were not present, we interviewed the market committee and/or other market sellers who also had some knowledge of the sales of cassava stems. The interview questions to the seed sellers addressed their sources of seed, prices, volumes and types of transactions. A final workshop was organized with the NRCRI and Catholic Relief Service (CRS) research teams to discuss and validate the findings of the studies on farmers' demand for seed and the cassava seed system.

To relate data from interviews, FGDs and expert meetings to the five seed system functions, aspects of demand, and seed system interactions, as outlined in our theoretical framework, we performed a qualitative content analysis (e.g., Bengtsson 2016). In this analysis, we grouped the most-discussed topics and most-prominent issues that were mentioned by respondents. To analyze the structured questions from surveys in the three farming communities, we collated the data in a spreadsheet and used Microsoft Excel® for descriptive statistics. Resource persons from IITA headquarters in Ibadan, ADP agents in the study regions, and knowledgeable farmers in the study

sites supported the identification of cassava varieties via their local names and characteristics.

Results

Functioning of the seed system at the national level

Key informant interviews indicated that three government organizations in the seed system contributed to providing a legal framework, variety development, seed multiplication and seed dissemination. NASC is responsible for the legal regulation of the seed industry in Nigeria. Following its mandate, NASC assures the quality of all classes of seeds (i.e., breeder, foundation and certified seeds) that are produced by IITA, NRCRI, and other seed growers through certification. The main activity of NASC in the cassava seed system consists of registering seed producers and quality certification of their seed. In that role, NASC controls land preparation during mid-season and upon harvest to assure that cassava stems are true-to-type. Although the seed law restricts the multiplication and sale of non-certified cassava seed, this was not actively implemented at the time of our study. NRCRI has the mandate to conduct research on the genetic improvement, production, processing, marketing and utilization of root and tuber crops and agricultural extension to farmers. As such, NRCRI is the main producer of certified seed and a seed distributor of improved varieties to farmers. If the demand cannot be met by NRCRI by itself, it refers the clients to out-growers. The ADP carries out a nationwide agricultural extension program aimed at increasing the knowledge base and use of improved practices by farmers, including the use of improved varieties. Each state's ADP is a parastatal of the Ministry of Agriculture and all these ADPs fall under the Federal Ministry of Agriculture and Rural Development. ADP has the mandate to disseminate seed through the ADP offices, but this channel was not functional at the time of our study because of financial constraints. NRCRI therefore established alternative dissemination pathways through demonstration plots, non-government organizations (NGOs), state and federal distribution structures, farmer organizations, and farmers directly.

Apart from the government institutions in Nigeria, projects by international institutions support cassava breeding, multiplication and distribution. The BASICS project, implemented by The CGIAR Research Program on Roots, Tubers and Bananas (RTB) and led by the International Potato Center (CIP), for the first time established a certified seed value chain from breeder seed to the sales of certified seed via a decentralized network of village seed entrepreneurs in Nigeria's South-South, Southeast and North Central geopolitical zones. The village seed entrepreneurs have access to

early-generation cassava seed from foundation seed producers, which they multiply and sell to farmer-clients in the vicinity. This makes them major distributors of certified cassava seed in Nigeria, next to NRCRI. Since 2010, the program *HarvestPlus*, coordinated by the International Center for Tropical Agriculture (CIAT) and the International Food Policy Research Institute (IFPRI), supports the distribution of biofortified vitamin A cassava varieties. NextGen, a project led by Cornell University, in collaboration with IITA and NRCRI in Nigeria, aims at increasing the rate of genetic improvement in cassava breeding. Breeder seed production is scaled up through GoSeed, part of the business unit of the IITA Business Incubation Platform. Out-growers produce foundation seed by buying breeder seed from and selling foundation seed back to GoSeed.

Different to the actual mandate of ADP, which is the dissemination of certified seed to farmers, the network of ADP agents often act as *brokers* in the system. The ADP extension staff, called agents, facilitate stem sales among farmers, and between farmers and stem sellers by establishing contacts between the potential sellers and buyers. In that role, they contribute to seed dissemination and exchange of seed that is informally multiplied by farmers and other seed sellers. Also, NGOs, churches, and local governments contribute to seed dissemination and exchange. They purchase non-certified cassava seed from different sources and distribute the stems for free to farming communities as a way of support or gaining popularity in rural areas. The link to and between these institutions and farmers, and between farmers is built largely by informal seed sellers. These sellers range from farmers who sell 50–100 bundles (one bundle = 50 cassava stems one meter long) a year to large commercial traders, who sell 2,000 bundles or more a year. During the planting season, stems are traded on village markets or specialized cassava markets. We identified three types of informal seed sellers that commonly exist in Nigeria's cassava seed system:

- Farmer seller: a cassava farmer who sells at least 50 bundles of stems a year from his/her own field as a by-product of root production.
- Stem farmer: a cassava farmer who has a deliberate strategy for stem production and selling (at least part of the cassava fields is planted with the aim to sell stems).
- Stem trader: a trader who does not grow his/her own cassava fields to produce seed, but buys and sells stems, sometimes across long distances.

Farmers make up the largest and most diverse group of actors in the seed system. They continuously source and share cassava stems among themselves and with seed sellers. Besides producing cassava roots for different purposes,

Table 2. Presence and role of seed system actors in the three study sites; ADP = Agriculture Development Program.

	Ibiaku Ntok Okpo, Akwa Ibom	Umuohuodi, Imo State	Ashina, Benue State
ADP	Used to actively distribute new cassava varieties, but stopped when farmers had access to new varieties	Low presence and influence in the distribution of quality seed and new varieties	Very active role in distributing new cassava varieties and facilitating seed sale
Farmer seller	Active role, have access to recent varieties	Active role, sell stems mostly on markets and some also on demand from their farm. They have no access to new varieties	Actively selling stems, have access to new varieties and sell on-demand from their farms or ad hoc along the road during planting season
Stem farmers	Deliberately produce seed of recent varieties	Not present	Not present
Stem trader	Not present	Buy stems from seed sellers in the community	Trade with producers and buyers in community, facilitated by BNARDA
Others		Specialized stem markets exist, where clients come from far	Catholic Church/Catholic Relief Service (CRS) create market linkages

some farmers also engage in selling, multiplying and trading stems. As such, the farmers can perform different functions in a seed system.

Functioning of the seed system at the local level

The presence and role of seed system actors varied across the three study sites (Table 2). In **Ibiaku Ntok Okpo**, the Akwa Ibom State Agricultural Development Program (AKADEP) used to play an active role in seed dissemination. The ADP agents often facilitate cassava stem sales between sellers and buyers in the community. Four of the 12 seed sellers interviewed in Ibiaku Ntok Okpo indicated that they obtained improved cassava varieties via the ADP in the past years. The seed sellers sold the cassava stems to farmers in the community, which led to the dissemination of improved varieties. Recently, the AKADEP reduced seed brokering, when improved varieties were available among farmers in the community. Only in Ibiaku Ntok Okpo, we identified *stem farmers* who specialized in planting cassava for the sale of stems. They reported to sell significantly more bundles of cassava stems than the interviewed *farmer sellers*. Out of the six interviewed stem farmers, two indicated obtaining new varieties from the market, two from seed sellers in the BASICS project, and four from AKADEP.

The cassava sector in Imo State is characterized by a relatively low intervention of formal actors and low adoption rates of improved varieties as compared to other states. Only 3 of the 12 interviewed cassava seed sellers in **Umuohuodi** reported to have access to new varieties. The others explained to

have no contact with ADP, no money to buy stems of new varieties, and no other sources to obtain new varieties. Some farmers in the community reported that they regularly sold stems in relatively large amounts at the cassava stem market to clients from the community and also from other Local Government Areas and neighboring states. Farmers explained that the stem buyers often came from areas where the soil was infertile and cassava plants did not produce enough cuttings for planting. The farmer sellers also cut stems on demand to sell them from their farm. Their clients know about them through contact with former buyers or through seeing the cassava field of the farmer seller.

The ADP in Benue State, Benue Agricultural and Rural Development Authority (BNARDA), plays a central role in the distribution of cassava seed and new varieties. BNARDA typical sources for stems of improved varieties are HarvestPlus out-growers, IITA, NRCRI, and the Roots and Tubers Extension Program. In addition, seed sellers indicated that BNARDA commonly sourced stems via aggregators from distances of up to 60 km to facilitate seed sales to farmers in the vicinity of their offices. BNARDA has been active for a long time and is well connected to farmers, especially in **Ashina** where a retired ADP extension worker lives. A community leader of Ashina explained that the retired extension worker received improved cassava varieties from BNARDA in 2011 and 2012 to distribute them to farmers for further multiplication as part of the general ADP plan. Some of the farmers, who originally received the improved varieties from BNARDA for multiplication, have become important seed sellers in the community. The local seed sellers in Ashina can be categorized as *farmer sellers*. Some sellers regularly cut stems from their field and advertise the sale by placing a heap of stems along the road. Others sell on-demand on a referral basis, mostly through the ADP and previous clients. The Catholic Church and CRS connect seed sellers and buyers by advertising improved varieties and sales points.

Farmers' demand for seed

Varietal traits

Farmers at the three study sites indicated to have grown a portfolio of one to six different cassava varieties per household. The use of local names often refers to the characteristics of these varieties. For example, in Ibiaku Ntok Okpo, farmers call a variety, formally known as "TME-419," "Long John" because of its distinctive stem architecture with a non-branching and very straight stem. All varieties in use have traits that farmers like and traits they dislike. For example, farmers in Umuohuodi explained:

Table 3. Most popular cassava varieties (grown by more than 10% of farmers) in the three study communities and distribution among farmers.

Study site	Name used by farmers	Formal name	Release date	Farmers who grow variety
Ibiaku Ntok Okpo, Akwa Ibom State (N = 30)	6-Months/Give Me Chance	K195/K29	Not released, IITA field trials in 1976	100%
	Long John/TME 419	TME-419	2005	70%
	Vitamin A/ vitamin C/ vitamin E	TMS 011368	2011	43%
	Stainless	*Unknown*	Unknown, recently	17%
	Five-Five	TMS 30572	1984	13%
Umuohuodi, Imo State (N = 30)	Abeokuta	*Landrace*, also known as Imo Best/Dabere	*not released*	100%
	Nwaocha	*Landrace*	*not released*	90%
	Ahunna/Vuo Lee	*Landrace*	*not released*	80%
	Akpu Red	*Landrace*, also known as Nwaibibi	*not released*	60%
	Agric	*Landrace*	*not released*	20%
	Egbe nwuri	*Landrace*	*not released*	17%
	Agu Egbu	*Landrace*	*not released*	17%
Ashina, Benue State (N = 47)	TMS 1368	TMS 011368	2011	62%
	Akpu Fefa	*Unknown*	Unknown, long time	60%
	TMS 30572	TMS 30572	1984	45%
	TMS 0505	TMS 980505	2005	40%
	Akoyawo	TME 7 (Oko-Iyawo)	*Landrace*, identified in 1971	30%
	Dangbo	TME 2 (Odongbo)	*Landrace* and released as variety in 1986	15%
	TME 419	TME-419	2005	9%

In some cases farmers used different names for the same variety (e.g., "6-Months" and "Give Me Chance") Release dates/date of identification were identified from http://my.iita.org/accession2/ and http://seedtracker.org/cassava/index.php/released-cassava-varieties-in-nigeria

> Nwaocha is very good for fufu, as the color is usually brighter than other varieties. It is the preferred variety for fufu and gari [indicating high starch content. However,] … it is often eaten by rodents because it is sweet unlike other varieties.

> Abeokuta matures earlier than other varieties. [However,] … it absorbs plenty of water in the rainy season and retains a small amount of water during the dry season.

In FGDs, farmers described the characteristics of their most popular varieties in the studied communities (Table 3). In Ibiaku Ntok Okpo, farmers explained that the variety 6-Months/Give Me Chance is grown in almost every household because it matures within six months and its yields are reasonably high. However, the variety does not store well underground, as it

decays relatively early. The farmersdid not appreciate the earlier used varieties "Ekauya," "Paya," and "Afiokpo" and gradually stopped planting them.

Farmers indicated that they commonly asked for seed from other farmers or seed sellers to try out new cassava varieties (reported by 7 of 20 farmers in Ibiaku Ntok Okpo, 4 of 15 farmers in Umuohuodi, and 7 of 11 farmers in Ashina). The Akwa Ibom ADP recently introduced the variety "Stainless" (formal name unknown), which is mostly in the hands of medium and large farmers. In FGDs, participants explained that those farmers shared the seed of the variety with other farmers in the community and sometimes asked for money for the stems. Similar patterns of variety diffusion in communities were reported in FGDs in Ashina. In Umuohuodi, farmers recalled the varieties "Nwaocha" and "Agric" to have been in the community for about 10 years. The other varieties had been there for much longer, which farmers were unable to trace back.

FGDs with farmers indicated that in Umuohuodi and Ibiaku Ntok Okpo, decisions on varietal choices, sources for planting material, and marketing of produce were mostly taken together by men and women. In Ashina, these decisions were commonly taken by men. Interviews with key informants and seed sellers showed that men and women both asked for specific varieties when sourcing stems, but they did not have clear differences in variety preferences, i.e., they appreciated the same varieties for similar traits. One female cassava stem seller in Ibiaku Ntok Okpo, however, explained that "new varieties are mostly in the hands of men."

Quality of seed

In all three study sites, stem sellers reported on the quality attributes that men and women sought: robust fresh stems, white/cream color of the stem, shorter internodes, free from mechanical damage, diameter (not too small),

Table 4. Mean size of areas planted with cassava per farmer and sources of cassava stems used by the farmers from different categories in three study sites in the last 12 months.

Study site	Farmer category	Mean size cassava areas in ha, (standard deviation)	Own-farm only (%)	Off-farm only (%)	Combination (%)
Ibiaku Ntok Okpo	Small (n = 10)	0.4 (0.1)	10	30	60
	Medium (n = 11)	1.5 (0.4)	18	27	55
	Large (n = 9)	3.4 (1.1)	78	0	22
Umuohuodi	Small (n = 9)	0.3 (0.1)	67	0	33
	Medium (n = 14)	1.4 (0.5)	71	0	29
	Large (n = 7)	3.4 (1.2)	43	14	43
Ashina	Small (n = 9)	0.4 (0.1)	89	0	11
	Medium (n = 26)	1.2 (0.4)	81	4	15
	Large (n = 12)	4.1 (2.7)	92	0	8

free of termites, and early maturity. Farmers commonly identify the quality of stems by observing the color of the stem pulp. In this process, they also consider the freshness of the young cassava leaves on the stem. Stems with white powdery substance are considered to be of poor quality. The longer dry season in Ashina, compared to the other two study sites, makes it more difficult to keep the stems in good condition for planting. Some farmers explained that they planted the cassava stems in swampy areas to conserve them until the planting season starts. However, most of the seed was produced from fresh cuttings from farmers' fields. According to stem sellers in Ashina, their clients considered "disease-free" as an important trait in selecting stems. However, across all study sites, the farmers did not mention disease infestation or other reasons that would indicate degeneration of planting material in the individual interviews nor in the FGDs. They usually sourced seed from other farmers or traders for other quality aspects.

Seed sourcing

In the last 12 months, farmers across all three study sites used cassava seed from multiple sources in a single season: their own fields, relatives/friends/

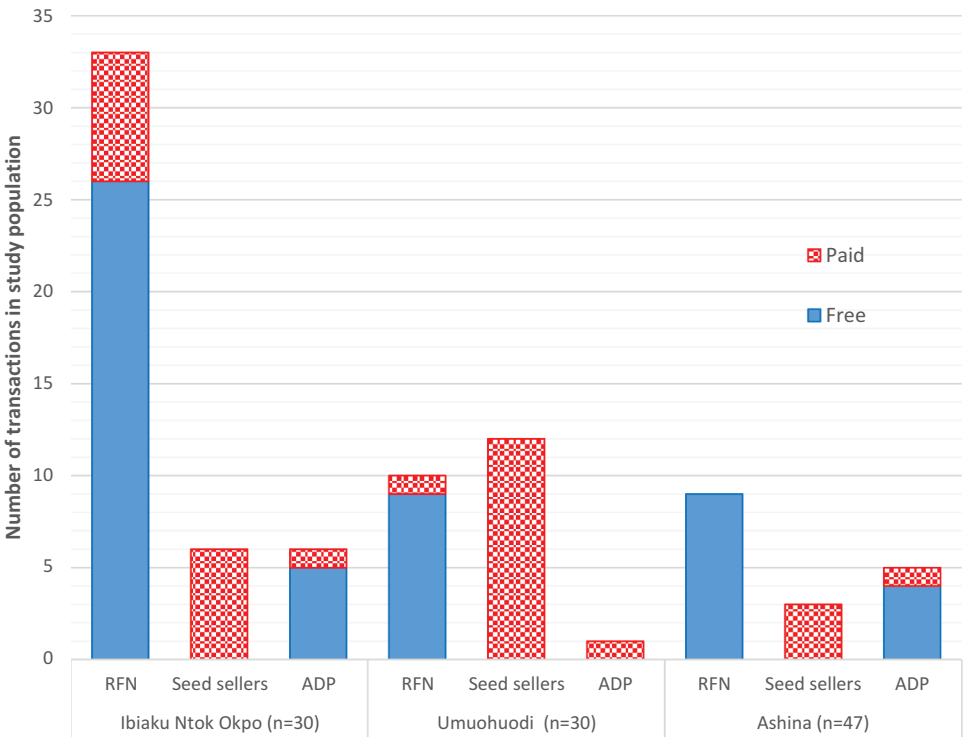

Figure 3. Different sources and number of seed transactions in the sample of farmers in the last 12 months. RFN = Relatives, friends or neighbors; ADP = Agriculture Development Program.

neighbors (RFN), the ADP, and traders. The dominant source of stems was farmers' own fields. Off-farm seed sourcing varied between study sites and farmer categories (Table 4). In Ibiaku Ntok Okpo, most small and medium farmers sourced stems from their own farms or in a combination of own- and off-farm, whereas the majority of large farmers sourced exclusively from their own farms. In Umuohuodi and Ashina, most farmers sourced planting material exclusively from their own farms. The group of large farmers in Umuohuodi was the exception: many of them sourced their planting material off-farm only (14%) or in combination (43%).

The major off-farm source for seed across all study sites in the past 12 month was RFN (Table 5 and Figure 3). According to interviewed farmers, it was normal to share seed without payment within the community. In Ibiaku Ntok Okpo, farmers indicated that in some parts of the community, farmers were traditionally allowed to take cassava stems from fields without prior agreement with the owner as long as the stems were used for planting in one's own fields and not for commercial purposes. In other parts of the community, it required negotiation and possibly payments in cash or in-kind (e.g., seed or labor on other farms). With an increasing commercialization of the cassava sector, cash transactions for sharing seed with RFN have become more common than before. In Ashina, farmers explained that while they shared seed with subsistence farmers in the community for free, they expected commercial farmers to pay for the stems. Next to seed exchange with RFN, farmers across all study sites sourced stems from seed sellers and via ADP-facilitated seed exchange in the last 12 months (see Figure 3). In Umuohuodi, the ADP was represented less prominently than in the other study sites, with only one transaction in the study population. Instead, a larger share of cassava stems was sourced from seed sellers (12 transactions in the last 12 months).

According to FGDs and individual interviews in Ibiaku Ntok Okpo, most farmers who sourced stems off-farm were men. A female farmer in Ibiaku Ntok Okpo, who regularly sold cassava stems explained:

> It is exceptional for me to source stems from the Ministry of Agriculture. Other women do not have that opportunity; they are afraid to express themselves. They only plant cassava for home consumption and not to sell roots, like I do.

Quantity of seed

The data presented in the previous section showed a considerable part of seed transactions from off-farm sources. However, data on the total volumes of cassava stems showed that the majority of stems (more than 80% on each site) were sourced from farmers' own fields in the last 12 months (Table 5).

Table 5. Volumes of cassava planting material that farmers used from their own field and sourced off-farm in the last 12 months; RFN = Relatives, friends or neighbors; ADP = Agriculture Development Program.

Study site	Mean volumes in bundles, (standard deviation)	Own field	RFN	ADP	Seed sellers
Ibiaku Ntok Okpo (N = 15)	43.9 (38.2)	81%	17%	0	2%
Umuohuodi (N = 15)	145.5 (113.8)	96%	2%	0	2%
Ashina (N = 47)	84.8 (63.9)	91%	4%	4%	1%

Figures are based on data from second study phase only. Therefore, not all transactions as presented above are included.

Farmers in Ibiaku Ntok Okpo sourced 17% of seed from RFN, and seed from other off-farm sources constituted only a relatively small proportion.

A shortage of planting material of farmers from their own fields was reported as the main reason for off-farm seed sourcing (reported by 10 of 20 farmers in Ibiaku Ntok Okpo and by 9 of 15 farmers in Umuohuodi). The farmers indicated a shortage of planting material due to theft, infestation by termites, inadequate availability of their own stems, and the need for more stems to expand farms. In Ashina, only 3 of 11 farmers reported a shortage of planting material from their own fields. These farmers were planning to expand their farms.

Discussions with stem sellers showed a tendency that the larger the average purchase per client, the larger the percentage of male buyers. One seed seller explained that he favored male clients since they were willing to pay more, resulting in delayed delivery to female clients. During the validation workshop, the participants suggested that women were normally part of a social network in which stem sharing was common, reducing their willingness to pay for stems.

Discussion

Actors and interactions on the supply side

Our study showed that a wide range of formal and informal actors were involved across all seed system functions. Similar to other RT&B crops, the public sector did not have the capacity and private sector companies were not interested to engage in seed multiplication and dissemination (Gibson 2013; Almekinders et al. 2019). The limited capacity of the ADP to disseminate certified seed to farmers already created a gap in the dissemination of new varieties in Umuohuodi and would possibly create a similar gap in Ibiaku Ntok Okpo in the future. The importance of informal seed sellers to provide seed system functions in such situations was emphasized for RT&B crops (Andrade-Piedra et al. 2016; Rachkara et al. 2017) as well as for

other crops (Sperling et al. 2020a). In particular, for vulnerable groups, during stress periods and for seed of specially adapted crops, informal seed traders catered for underserved markets and reached out to farmers in the last mile (Sperling and McGuire 2010; Kansiime and Mastenbroek 2016; Sperling et al. 2020b).

Our findings showed that seed exchange with RFN could enhance farmer's access to seed in case of shortages and the distribution of new varieties once they reached the community, similar to other RT&B crops in Africa (Coomes et al. 2015; Tadesse et al. 2016; Adam, Badstue, and Sindi 2018; Almekinders et al. 2019). All seed that farmers in our study reported on, was non-certified seed produced and sourced from farmers' fields and disseminated via local trade and farmer seed networks. Also a data analysis of six countries and 40 crops showed that farmers accessed 90.2% of their seed from informal systems (McGuire and Sperling 2016). It is therefore not likely that laws to restrict informal sales of cassava seed, other than certified by NASC, can be enforced in Nigeria.

Demand-side of the seed system

In regard to farmers' demand, access, availability and use of seed varied between the seed systems in the three communities. Farmers across all study sites maintained and gradually replaced a portfolio of varieties. As presented in other studies, the prevailing portfolio of varieties in all study sites reflected varietal choices that are driven by agro-ecological conditions, cultural preferences, and market opportunities for produce, but limited by the access from the supply side (Pircher, Almekinders, and Kamanga 2013; Tadesse et al. 2017). Hence, farmers might use different varieties because they did not have access to a variety that combined their desired traits. Keeping multiple varieties can also be driven by the interest of farmers to have traits for different production uses, e.g., for bitter and sweet cassava varieties (Thiele et al. 2020). In either case, this situation indicates a demand for new, better adapted cassava varieties.

Our exploratory study approach revealed that variations in demand not only occurred between different communities, but also within communities and households. In Ibiaku Ntok Okpo, the intensity of off-farm seed sourcing increased from large farmers to small ones. Also Sperling and McGuire (2010) found a significantly higher share of poorer farmers sourcing seed of different crops and in different African countries from informal markets. Their explanation was that poorer farmers often ran out of seed from their own farms, whereas richer farmers bought seed to access new varieties. Social differentiation by gender illustrated variations in demand, in particular that women had less access to new varieties and

were not able or willing to pay for larger amounts of cassava seed. We did not explore in-depth gender-specific trait preferences. Different preferences for varietal traits in cassava by men and women in Nigeria were found in other studies (Bentley et al. 2017; Wossen et al. 2017; Teeken et al. 2018).

Our findings on quality criteria for planting material refer to physical condition of the stems, but not to viruses and other pathogens. This can be explained by the absence of pathogens that can cause stem degeneration in Nigeria. The largest threat, cassava brown streak disease, is currently present in east and central Africa but has not yet affected west Africa (Patil et al. 2015). If cassava viruses and other diseases reach Nigeria, farmers' demand for seed quality might shift the focus on disease-free planting material.

Supply-demand interactions

The market for cassava seed across the study sties was driven by a combination of three types of demand, i.e., desired varieties, and quantity and quality of seed. Our study indicates that public seed distribution schemes are unlikely to reach farmers with cassava seed that addresses heterogeneous demands. Some scholars argue that farmer-owned seed systems address the variation in demand across social groups, cultural identities and inequalities better (Bezner Kerr 2013). However, without linkages to the formal sector, these seed systems often lack the influx of new varieties and a regular turnover of those (Gibson 2013). In our study, we observed this in Umuohuodi, where the varieties in use had been in the community for 10 years or longer and consisted of landraces only.

Another model to supply quality seed and improved varieties is farmer seed enterprises that are recognized by the legal framework and authorized to produce certified seed (e.g., David 2004). These models have been promoted since the 1980s, but so far they have not reached scale and sustainability to become prominent for seed supply (Almekinders et al. 2019). The BASICS project, which is active in the three project areas, builds on such a model. A recent study on the project concluded that decentralized seed multipliers, called village seed entrepreneurs, might be able to satisfy famers' demand for cassava seed but needed continued programmatic support to do so (Bentley et al. 2020).

Both informal seed sellers and village seed entrepreneurs of the BASCIS project have the potential to contribute to disseminating quality seed and new varieties on the last mile. However, this can only work when recurrent demand for cassava seed exists or when seed sellers are empowered by the formal system. In this process, the flow of

information on various aspects of demand from farmers to early generation seed producers and breeders becomes similarly important. Established village seed enterprises or empowered informal seed sellers know farmers' demand for seed that drives their business. To respond better to farmers' demand, they would need access to a wide array of varieties and influence early-generation seed producers and breeders about which varieties to produce. Such a feedback loop would allow farmers to better articulate their demand for seed toward the supply side in a continuous process.

Conclusions

We are aware that our exploratory study in the three farming communities is not representative of Nigeria. However, our findings help to explain variations in demand among the study sites, and to a smaller extent also among farmer types and gender. Moreover, our study indicates supply-demand dynamics: (i) farmers maintain an adapted portfolio of varieties, and dynamically source new seed via different channels, (ii) informal seed system actors contribute to the dissemination and exchange of seed where the public sector does not reach out. Seed sellers and village seed entrepreneurs have the potential to deliver seed on the last mile but lack access to new varieties. To close the gap in a process of demand articulation from farmers to breeders and producers of early generation seed, they need continuous support from formal actors.

While arguing for more demand-orientation in seed systems, we recognize the pitfalls of limiting the focus on seed system performance to farmers' demand alone. For example, an evaluation of client-oriented breeding schemes in Nepal showed that the operational seed-producer groups marketed only rice varieties that were already in the hands of farmers, but did not contribute to scaling out new varieties (Witcombe, Devkota, and Joshi 2010). Innovation in seed systems is based on continuous improvement and spread of varieties that also address challenges that farmers might not yet identify, e.g., outbreak of cassava brown streak disease. Making seed systems future-proof, therefore, requires a balance between demand-orientation to make seed attractive to farmers and foresight with other stakeholders to address future challenges and opportunities.

Notes

1. In this article we use the term "seed" not only in its "true" botanical meaning, but also in reference to planting material of vegetatively propagated crops. These include stems, roots, tubers, and suckers.

2. The sample included farmers from different villages in the community Ibiaku Ntok Okpo, namely Ikot Akpan Udo, Ibiaku Ata, Itak Ikotakpandem, Ikot Ofiong, Ibiaku Ikot Edet, Ikot Ukana, Nkara Obio and Nung Ukim.

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