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**Regulatory Options to Improve Seed Systems for Vegetatively Propagated Crops
in Developing Countries**

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ABSTRACT

In many developing countries, smallholder farmers cultivating vegetatively propagated crops (VPCs) have limited access to quality planting material. This constraint can limit both the yield of and returns on VPC cultivation. Yet policy and regulatory initiatives designed to strengthen access to quality VPC planting materials have been relatively unsuccessful to date. Part of the problem is the unique biological and economic characteristics of vegetative propagation and its distinctness from cereal crops, which dominate narratives on seed system reforms. Drawing on qualitative analysis of policy and practice, this study examines reform options related to quality assurance regulations in four crop-country combinations: cassava in Nigeria and Vietnam, and potato in Kenya and Vietnam. The study highlights theory and evidence on existing models of regulation; alternative models that may better incentivize cost-effective multiplication and distribution; and recommendations for policy, regulation, and investment in VPC seed markets. Findings indicate that regulations designed around strict and centralized quality control systems tend to limit market size, while more localized production systems are limited by both capacity and reach. These findings suggest the need for alternatives that balance a permissive regulatory regime with decentralized production systems, grassroots capacity development, market surveillance, and systems that integrate internal (producer-level) quality assurance with external (regulatory) quality assurance.

Keywords: Seed systems; seed policy; vegetatively propagated crops; seed market regulations; seed quality assurance; cassava; potato; Kenya; Nigeria; Vietnam

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ACRONYMS

ADC	Agricultural Development Corporation, Kenya
ASTGS	Agricultural Sector Transformation and Growth Strategy, Kenya
CIP	International Potato Center
CMD	cassava mosaic virus disease
COMESA	Common Market for Eastern and Southern Africa
EWOCAS	Economic Community of West African States
FGD	focus group discussion
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
KEPHIS	Kenya Plant Health Inspectorate Service
KII	key informant interview
MARD	Ministry of Agriculture and Rural Development, Vietnam
MoALF	Ministry of Agriculture, Livestock and Fisheries, Kenya
NASC	National Agricultural Seed Council, Nigeria
NGO	nongovernmental organization
PCN	potato cyst nematode
RTB	CGIAR Research Program on Roots, Tubers and Bananas
VPC	vegetatively propagated crop
VSE	village seed entrepreneur

INTRODUCTION

Vegetatively propagated crops (VPCs) play an important and varied role in many agricultural production systems and in people's consumption choices throughout much of the developing world. An estimated 300 million people living in poverty throughout the developing world depend on at least one type of root, tuber, and banana crop for their livelihoods, and this figure is expected to continue growing over time (Thiele et al. 2017). Despite their importance, there are significant variations in yields among root, tuber, and banana crops across developing countries, with per-hectare output well below what breeders and agronomists believe is biologically feasible under optimal agroclimatic conditions and crop management practices. Similarly, there is significant variation in the returns on cultivating these crops, whether for farmers' own household consumption or for local, domestic, or export markets.

One pathway to increasing VPC yields and returns is through the use of quality planting materials by farmers (Almekinders et al. 2019). These planting materials—generally referred to as “seed” throughout this paper—are cuttings, stems, buddings, tubers, or other vegetative material used to asexually propagate a plant that is genetically identical to its parent. Both market and nonmarket systems that supply seed to farmers are recognized as an integral part of efforts to boost VPC yields and returns and, more generally, to support agricultural development (Cromwell, Friis, and Turner 1992; Jaffee and Srivastava 1994; McGuire and Sperling 2016).¹ Systems that deliver seed of both good genetic and physical quality are an essential complement to other yield-enhancing inputs and crop management practices.

This study is motivated by the question of whether there are appropriate quality assurance models that can increase availability of and access to quality seed for VPCs cultivated by small-scale, resource-

¹ To avoid confusion, note that we refer to “seed systems” throughout this paper as a generic phrase to describe any system in which planting material is produced, exchanged, and used. This system covers true biological seed as well as asexually, clonally, or vegetatively propagated materials. For the purposes of this paper, cassava “seed” refers specifically to propagation material derived from stems or stakes cut from a mature plant, while for potato, the term refers to seed tubers used for planting.

poor farmers while simultaneously minimizing the risk of spreading pests and diseases that might threaten their yields and incomes.²

Most developing countries have explicit policies and regulations that govern seed systems and markets, and many have policies and regulations that aim to address this question in broad terms. During the past two decades, some governments have actively explored changes to these policies and regulations, driven largely by new technological opportunities; by growth and development concerns; or by the need to comply with international trade agreements, conventions, and treaties (Spielman 2020; Spielman and Kennedy 2016; Louwaars, de Boef, and Edeme 2013). But the phytosanitary, physiological, and physical qualities of VPC seed—irrespective of genetic improvement—rarely garner attention in the formulation and implementation of these policy and regulatory reform efforts.

VPC seed systems have not featured prominently in these efforts partly because of the unique challenges associated with VPC seed and the limited attention they receive when compared with cereal seed systems in national strategies for agricultural development. Common characteristics of VPCs include low multiplication rates in seed production, bulkiness and perishability in storage and transport, and high susceptibility to pests and disease at all stages of seed production and use (Kapinga 2013; Gibson et al. 2009; Fuglie et al. 2006). These characteristics tend to limit the temporal and spatial reach of VPC seed systems and markets, and thus have implications for seed accessibility and affordability for smallholder farmers.

VPC seed systems also share certain commonalities with many cereal seed systems—commonalities best framed in economic terms. First, VPC seeds are credence or experience goods: their genetic and physical quality cannot be observed by a farmer at the time of exchange, thereby making it difficult to assess their utility or value in use. These problematic exchanges can, in certain situations, imply asymmetries of information between seed seller and farmer that can crowd out sellers of higher-

² Throughout this paper, we refer to “pests and diseases” as shorthand for seed- and soil-borne pests and diseases that are directly affected by VPC seed quality. Many other pests and diseases affect VPCs as a result of other biological phenomena, crop management practices, or other factors, but are beyond the scope of this paper.

quality seed and encourage the entry of sellers of lower-quality seed into the market, thereby reducing the efficiency gains expected from market exchanges (Akerlof 1970).³ In other situations, interventions designed to address asymmetric information still may not sufficiently resolve the basic demand-side challenges posed by credence goods in the marketplace.

Second, VPC seeds embody gains from innovation—improvements integrated into the seed as a result of plant breeding or good quality assurance in seed production—that are difficult for the innovator to appropriate. A farmer who purchases VPC seed can, in the absence of a law or contract to the contrary, simply save a vegetative portion of the plant for use as seed in a subsequent season or time period. This fact implies the generally widespread availability of low-cost substitutes for purchased seed in the form of farmer-saved or informally exchanged seed, albeit of unknown quality with pest and disease loads that may be increasing over time.

The extensive literature on seed market frictions in developing countries suggests that regulations related to quality assurance may be a remedy to the information problem (e.g., Pal and Tripp, 2002; Tripp and Rohrbach 2001; Morris 1998; Tripp and Louwaars 1997), while intellectual property rights may be a remedy to the appropriability problem (Spielman and Ma 2016; Eaton, Tripp, and Louwaars 2006; Lesser 2000). Quality assurance regulations such as seed certification and truthful labeling laws can provide farmers with information on the source of the seed, production date, expected germination rate, genetic and physical purity, and other indicators that signal quality to farmers, drive low-quality producers from the market, and increase the efficiency gains of the market exchange. Quality assurance systems internal to a seed producer can provide similar outcomes (Gildemacher et al. 2017), provided that external monitoring (or the threat of external monitoring and consequences for regulatory noncompliance) inhibit rent-seeking behavior.

³ The term “market” used in this context refers to any exchange of seed between two individuals, and may include cash- or credit-based transactions between agents in a formal marketplace, or less formal barter or contract arrangements between neighbors or traders. The nature of the transaction should not affect the analytical results of the Akerlof (1970) “lemons market” when applied to seed exchanges in our context.

Relatedly, intellectual property rights reward the owner of the variety by implicitly assigning a claim over the productivity gains accruing from the seed's use by a farmer. The literature on these remedies has focused primarily on cereal crops such as rice, wheat, and especially hybrid maize⁴ (Naseem, Spielman, and Omamo 2010; Pal, Tripp, and Louwaars 2007; Koo, Nottenburg, and Pardey 2004) but is relatively silent on VPCs, whose unique characteristics such as low multiplication rates, perishability, and pest and disease susceptibility are much more significant issues.

VPC seed systems—like all seed systems—are a matter of political economy. Different actors construct competing framings, use different language, and create advocacy coalitions to advance their respective interests in policy change processes that influence seed system development (Hassena, Hospes, and De Jonge 2016; Scoones and Thompson 2011; Kloppenberg 1988, 2010). In other words, it is impossible to analyze seed system policy from a purely technical perspective or as an exercise in economic efficiency analysis without recognizing that future outcomes are also shaped by competing actors, interests, coalitions, and power dynamics.

This study examines three research questions. First, what types of public policies and regulations govern quality assurance in VPC seed systems? Second, how do these policies and regulations influence access, availability, and quality of VPC seed for smallholders? Third, what alternative strategies might be employed to increase access, availability, and quality of VPC seed for smallholders?

At the heart of this study is a question about which quality assurance systems effectively balance the need to increase access to and availability of quality VPC seed for smallholders while also minimizing the biotic threats that accompany low-quality seed production and use. Drawing on qualitative analysis of both policies and practices, this study examines specific policy options for developing countries by exploring quality assurance regulations for four crop-country combinations: cassava in Nigeria and Vietnam, and potato in Kenya and Vietnam. The study highlights both the theory and practice driving

⁴ The productive and economic value of hybrid maize is conferred by *heterosis*, or the yield gains realized by crossing inbred parent lines. These gains are generally strongest in the first generation (F1) of hybrid seed and decline rapidly in subsequent generations, thus requiring farmers to purchase new F1 seed each season to continually realize these gains. Similar gains are not observed in self-pollinated crops such as rice and wheat, such that harvested grain can be saved for use as seed in a subsequent season without significant genetic depreciation, although physical depreciation may occur due to treatment and storage practices.

existing models of regulation; offers alternative models for VPC production, distribution, and marketing; and recommends several novel policy, regulation, and investment options in VPC seed markets.

The study also makes a unique contribution to the literature on the policy dimensions of seed systems in developing countries by emphasizing quality assurance for a class of crops that are typically overlooked in the analysis, design, and implementation of seed regulation. The policy literature on seed systems has revolved almost exclusively around varietal improvement in cereals, neglecting both VPCs and the issue of phytosanitary, physiological, and physical quality (irrespective of genetic improvement) (see, e.g., Thiele et al. 2021; McEwan et al. 2015). In fact, we know of no scholarly work on regulatory frameworks for VPC seed systems in developing-country contexts beyond those prepared as part of this study.

CASE SELECTION AND DATA SOURCES

The crop-country combinations selected for this study were chosen to provide variation in terms of the crop's use or uses in the economy (i.e., subsistence/consumption versus commercial/industrial); the nature of the crop's seed systems in the selected country (i.e., formal and regulated versus informal and unregulated),⁵ and the research team's own familiarity with these countries' seed systems, markets, and policies. Necessarily, VPCs and VPC seed systems are heterogeneous across both crops and countries: significant differences exist in crop reproductive biology, the material used for planting, the commodity's economic and cultural value, and the context in which it is cultivated, exchanged, processed, and consumed. The selection of cases here aims to capture several key dimensions of this heterogeneity while also highlighting commonalities, with the aim of developing a methodology that can be extended to the study of other VPC crop-country combinations and provide a basis for a more generalizable framing of the policy and regulatory issues and options for VPC seed systems.

Potato in Kenya was chosen for its importance in the country's agricultural development strategy, its widespread consumption, and the extent of the informal seed system, but also because of recent growth in a more commercial/industrial use of potato and a formal seed system. Cassava in Nigeria was chosen due to the crop's central role in successive agricultural development strategies of the country, its widespread production and consumption, its role in value addition (i.e., processing into *gari* and chips that are then sold commercially for consumption purposes), and an almost universally informal seed system. In Vietnam, both crops were chosen to explore their different contexts. Potato is neither widely produced in large quantities nor consumed as a staple food, and is thus of marginal importance to the national development strategy. Yet it is increasingly important to Vietnam's agroprocessing industries, the urban commercial food sector, and international trade, which, in turn, may lead to an increasingly

⁵ Throughout this study, we refer to "informal" and "formal" seed systems as shorthand for the extent to which seed quality is regulated. But this characterization may also be pejorative in describing how farmers in "informal" systems save and exchange seed within their communities, and it suggests an unrealistically linear construction derived primarily from analysts' experiences with maize seed sector development in industrialized countries (Coomes et al. 2015; Louwaars, de Boef, and Edeme 2013; de Boef et al. 2010; Almekinders and Louwaars 2002). A more appropriate term might describe informal seed systems as "socially managed" or "developmental" in nature (Spielman and Smale 2017).

formal seed system. Cassava is almost exclusively a feedstock to Vietnam’s starch industry, not widely consumed as a food staple, and reliant on an informal seed system (Le et al. 2019). The uniqueness of each crop-country combination is explored in greater detail below; for the complete country studies, see McEwan et al. (2021) on potato in Kenya, Gatto et al. (2020, 2021) on cassava and potato in Vietnam, and Wossen et al. (2020) on cassava in Nigeria. Table 1 and Table 2 provide figures on cassava and potato area harvested, yield, and production in this study’s focal countries and in key comparator countries.

Table 1 Cassava area harvested, yield, and production, selected countries, 5-year average, 2014–2018

Country	Area harvested (ha)	Yield (mt/ha)	Production (mt)
Brazil	1,389,800	15	20,699,182
Cambodia	418,420	26	11,435,482
Colombia	218,395	10	2,159,869
Dem. Rep. of the Congo	4,063,311	8	33,068,762
Ghana	953,492	19	18,532,775
Nigeria*	6,464,931	9	58,472,749
Thailand	1,377,028	23	31,211,734
Vietnam*	547,103	19	10,394,865

Source: FAO (2020).

Note: * denotes focal country in this study.

Table 2 Potato area harvested, yield, and production, selected countries, 5-year average, 2014–2018

Country	Area harvested (ha)	Yield (mt/ha)	Production (mt)
China	4,833,840	18	86,088,602
Kenya*	160,952	11	1,663,130
Netherlands	158,447	43	6,741,581
Peru	315,616	15	4,764,321
United States	421,767	48	20,311,272
Vietnam*	22,183	15	324,460

Source: FAO (2020).

Note: * denotes focal country in this study.

Once crop-country combinations were chosen, data were collected from two distinct sources: (1) key informant interviews (KIIs) and focus group discussions (FGDs), and (2) publicly available documents and data. KIIs and FGDs represent the primary data sources used in this study. Identification of participants for the KIIs and FGDs was guided by the multistakeholder framework for intervening in

root, tuber, and banana seed systems (RTB 2016). Participants included representatives of government ministries and agencies, regulatory bodies, and research institutes; private companies and industry associations; international research centers; donor agencies; nongovernmental organizations (NGOs), farmers' associations, and other civil society groups; and female and male farmers. Participants were interviewed in 2017 using semistructured interview guides that were developed for each category of actor (IFPRI et al. 2019). The interview guides include a range of topics, including basic details about the interviewee and his or her role in seed production or use, understanding of VPC quality assurance standards and practices, and viewpoint on the effectiveness of current policies and regulations and their differential impact on female and male seed producers and users. Where just one or two respondents were present, discussions were conducted as KIIs, and where a larger number of respondents were present, they were conducted at FGDs. The difference between KIIs and FGDs pertains primarily to how the discussion is managed and how information is presented, discussed, validated, refuted, and revised by participants and the interviewer, with a larger group (FGDs) often allowing for more iterative processes and a single respondent (KIIs) allowing for greater depth in the inquiry.

Geographically, KIIs and FGDs were concentrated in regions where the focus crops were produced or where key stakeholders were concentrated. In Kenya, this meant that fieldwork was concentrated in two of the country's major potato-producing areas (Meru and Nakuru counties) and the capital city, Nairobi. In Nigeria, focus was placed on key cassava-producing areas (Kaduna, Nasarawa, Niger, Ogun, and Oyo states); the capital city, Abuja, where key national agencies are based; and Ibadan, a cassava research hub. In Vietnam, emphasis was given to the major cassava-producing areas (Tay Ninh) and two potato-producing areas (Dalat and Dong Nai); the capital city, Hanoi; and the major commercial hub, Ho Chi Minh City. KIIs and FGDs lasted between one and a half and two hours. Although almost all interviews were held in English, several interviews were also conducted in other languages, with or without the assistance of professional translators, depending on the situation. A total of 95 semistructured interviews involving 241 individuals were conducted (Table 3).

Table 3 Organizations and individuals interviewed, by country

Classification of interviewed organization or individual		No. of interviews conducted							
		Kenya		Nigeria		Vietnam		Total	
No.	Category	Org	Ind	Org	Ind	Org	Ind	Org	Ind
1	<i>Policymakers, advisors, and regulators</i>	5	14	4	28	5	17	14	59
2	<i>Public research agencies, institutes, centers, and stations</i>	4	11	7	67	5	13	16	91
3	<i>Individual and small-scale seed entrepreneurs and enterprises</i>	6	18	41	41	6	7	53	66
4	<i>Private companies and industry associations</i>	9	15	1	8	2	2	12	25
Total		24	58	52	77	18	39	95	241

Source: Authors.

Note: ind = individuals; org = organizations; interviews = key informant interviews or focus group discussions for this study.

Although care was taken by the research teams to minimize bias, there may be several sources of bias in the study, many of which are common to qualitative research of this nature. First, though the research teams interviewed all relevant organizations in Categories 1, 2, and 4 (effectively conducting censuses in each country) to the extent possible, interviewees in Category 3 were sampled from a larger, often unknown, population. Sampling necessarily raises the issue of bias. To minimize sampling bias, each country research team followed a similar selection process to the best of its abilities, focusing its interviews of cassava and potato entrepreneurs and enterprises on those who could potentially provide critical insights on the research questions. In some instances, this may have led the research teams to interview participants who were involved, either directly or indirectly, with the researchers' own institutions or projects. To minimize this potential source of bias, concerted efforts were made throughout the project's field activities to identify interviewees who were unrelated to or independent of the research teams' institutions or projects. Additionally, insights gained from interviewees were considered and triangulated against farm-household survey data, where available and relevant.

Second, by choosing the main production regions for the selected crops, the research team may have generated limited insight into the more marginal regions, where production, consumption, and market conditions varied significantly from the most common conditions.

Third, in all three countries, some members of the research team relied on translation when the participant did not speak English. In Vietnam, professional translation services were employed, while in the other countries, research team members or field assistants provided translation. At multiple points during the project, the research team held discussions to reflect on the implications of these potential biases and to review field notes, internal team correspondence, and written analyses to flag and remedy such biases.

Fourth seed users (farmers) were not included among study respondents shown in Table 3. In fact, farmers *were* interviewed in each country on their seed sources, uses, and preferences, either during the study or in related research projects that were used to inform this study (i.e., secondary data). The interviews conducted during this study did not follow a strict sampling procedure because the sheer magnitude of an unbiased sampling of farmers for each case study would have exceeded available resources. Therefore, we do not highlight findings from our interviews conducted with farmers, and instead rely on secondary data wherever possible.

The interviews were augmented by the collection and analysis of legislative documents, regulatory handbooks, technical manuals, project reports, research papers, economic and agricultural statistics, and other documents relating to agricultural development policy, seed systems regulation, and related issues. Many of these documents were collected from government agencies and websites, although material was also garnered from donor agencies, international organizations, NGOs, and companies. It is worth noting that in all three countries, there is relatively more material available on projects to promote improved cassava and potato varieties than on the structure and performance of the seed systems for these crops.

BACKGROUND: COUNTRIES, CROPS, AND CONTEXT

Potato in Kenya

Potato is Kenya's second most important food staple crop after maize (Kenya, MoALF 2016; Muthoni and Nyamongo 2009). Approximately 2–3 million tons⁶ of potatoes, worth about 40–50 billion Kenyan shillings (KSh; approximately US\$40–50 million), are produced each year (Kenya, MoALF 2016).

Cultivation is undertaken by just a few large-scale ware-⁷ and seed-producing farms, and an estimated 800,000 small-scale farmers located across 16 counties and cultivating the crop on land units averaging just 0.4–0.6 hectares (Tesfaye et al. 2010). Potato yields in Kenya typically range between 8 and 10 tons per hectare, well below the average yields of 40 tons per hectare in developed countries, but on par with the average in Africa south of the Sahara (Okello et al. 2017; Harahagazwe et al. 2018; Muthoni, Shimelis, and Melis 2013; Gildemacher et al. 2011). About 90 percent of these potato farmers cultivate the crop for both own consumption and income generation (Muthoni, Shimelis, and Melis 2013). An estimated 2.5 million farmers are also employed in Kenya's potato value chain, with considerable prospects for growth in the food processing industry (Kenya, MoALFI 2018; Laibuni and Omiti 2014).

The government of Kenya has articulated plans to expand potato production area, volume, and value, most recently in the National Potato Strategy (2016); the Big Four Agenda, a presidential initiative that highlights food security as a national priority (2017); and the Agricultural Sector Transformation and Growth Strategy (ASTGS) (2018). These plans require quality seed, an input that is in short supply throughout the country. In fact, the certified seed potato market in Kenya is extremely small: just 6,714 tons of seed produced on 403 hectares were certified in 2017. The parastatal Agricultural Development Corporation (ADC) and two private seed companies (Kisima Farms Ltd. and Charvi Ltd.) accounted for more than 75 percent of Kenya's certified seed potato production in 2017. When measured as a share of all seed potato sown by farmers in Kenya (irrespective of quality), this volume represents just 4–5 percent

⁶ Tons refers to metric tons throughout this paper.

⁷ Ware potatoes are those used for human consumption or for processing into other food or industrial products, rather than for seed.

of the estimated market (Muthoni, Shimelis, and Melis 2013; Schulte-Geldermann et al. 2013; Gildemacher et al. 2009).

Not surprisingly, most smallholders source seed from their own farms, from neighbors, or from market agents selling small ware potatoes as seed. Gildemacher et al. (2009) reported that 41 percent of potato farmers in Kenya periodically renew their seed after six seasons. Research indicates that these informal exchanges may contribute significantly to the spread of seedborne diseases and the persistence of soilborne diseases that reduce yields—namely, bacteria wilt, late blight, and more recently, potato cyst nematode (PCN) (Kaguongo et al. 2014; Muthoni, Shimelis, and Melis 2013).

The legislation governing Kenya’s seed sector is the Seeds and Plant Varieties Act (1972) and its subsidiary regulations, guidelines, amendments, and revisions. The law clearly states that uncertified seed is illegal in Kenya: no person may sell seed of a species that requires compulsory seed certification (known as “schedule 2” crops, which includes potato), unless it has been certified or otherwise meets a minimum standard prescribed for the class and species. Of course, ground realities depart widely from written law; farmers buy and sell seed potato among themselves, and NGOs, charitable foundations, and research organizations train farmers in how to produce and distribute high-quality but uncertified (“clean”) seed potato.

Meanwhile, Kenya’s seed policies and regulations continue to evolve with a growing focus on the formal seed market, with important implications for potato and other VPCs. The most recent amendments to the act (and its related policies, regulations, and guidelines) aimed to bring Kenya’s seed policies into closer alignment with international seed standards, domesticate regional obligations related to harmonized seed regulations, and highlight the role of certified seed in addressing emerging pests and diseases. These amendments have been central to the Kenyan government’s efforts to attract private investment—particularly foreign private investment—into Kenya’s seed sector. Meanwhile, Kenya’s transition to a new constitution in 2010 shifted a significant share of responsibilities for policy implementation—including seed policy implementation—from the central government to county governments, although the

Kenya Plant Health Inspectorate Service (KEPHIS) still maintains a central role as the country's autonomous regulatory entity in charge of seed certification and phytosanitation.

Cassava in Nigeria

Nigeria is the world's largest producer of cassava (Table 1), accounting for roughly 20 percent of the global cassava production. The crop is largely produced by farm households throughout much of the country as a staple food crop and as a source of income. It is also an increasingly important feedstock in agro-industrial processing (Wossen et al. 2017; Alene et al. 2012; Dixon et al. 2011). Yet Nigeria's cassava yields are at most half of the yields achieved in other major cassava-producing countries such as Thailand, Ghana, and Vietnam (FAO 2020; Wossen et al. 2019).

Nigeria's cassava seed system remains largely informal. Still, the use of stems from farmers' own production or local exchanges is the norm, contributing to the transmission of yield-reducing pests and diseases (Rabbi et al. 2015; Kapinga 2013; Gibson et al. 2009). Wossen et al. (2017) reported that although about 60 percent of farmers in Nigeria cultivate improved cassava varieties, most rely on this informal system to obtain seed. Specifically, they found that stems saved from their own crops or obtained from friends, relatives, or neighbors are the primary planting materials for about 70 percent of all cassava farmers, while an additional 6 percent obtained materials from local markets, and 17 percent from semiformal and formal sources such as government extension services, research institutions, and processors.

Like Kenya, the seed system in Nigeria is governed by a legal framework. This framework was initially set forth in the 1992 National Agricultural Seeds Act (Decree no. 72) and, with subsequent amendments, formally established the laws governing the national seed system and the public agencies required to manage this system, including the National Agricultural Seed Council (NASC), which serves as Nigeria's main regulator for seed quality assurance. The 1992 act was replaced by the 2019 National Agricultural Seeds Act, which came into effect in May 2020, after this study was conducted. The 2019 act

includes several changes to the 1992 act worth noting: recognition of third-party certification, increased penalties for counterfeiting, and recognition of propagation materials as “seed” for certification of VPCs.

But Nigeria’s cassava seed system is distinguished more by programs and projects than by legal frameworks. Early efforts to create a functional seed system date back at least to the 1970s, when the International Institute of Tropical Agriculture (IITA) and the National Root Crops Research Institute bred tropical manioc selection varieties that were resistant to cassava mosaic virus disease (CMD) (Nweke 2010; Nweke et al. 2002). During the 1980s, NGOs such as Catholic Relief Service and international development organizations such as the International Fund for Agricultural Development played a key role in distributing these varieties to farmers throughout the country’s cassava-growing regions, often working alongside various government development agencies.

In the early 2000s, several programs furthered efforts to create a more formal seed system for cassava: the Root and Tuber Expansion Program initiated under the 2002 Presidential Initiative on Cassava and the Cassava Transformation Agenda of the 2011 Agricultural Transformation Agenda (Donkor et al. 2017). These initiatives prioritized the distribution of improved cassava varieties, pursued regulatory reforms in the seed system, and created incentives to stimulate private investment in cassava processing. They were followed by initiatives such as the High-Quality Cassava Flour initiative, which aimed to substitute 10 percent of wheat flour used in breadmaking and other value-addition processes with cassava flour; the Cassava Bread Development Fund, which provided funds to help increase demand for quality cassava as a feedstock for agroprocessing; and the Growth Enhancement Scheme, a targeted-input subsidy program that distributed improved cassava varieties (FMARD 2014; Asante-Pok 2013). More recently, a number of projects have been undertaken to improve the distribution of new varieties and clean planting material, with specific emphasis on creating more sustainable and commercial pathways.

Potato and Cassava in Vietnam

While both cassava and potato are referenced in Vietnam's various strategies for economic growth and agricultural development, they are not major crops in the country. The respective area under cassava and potato in the country totaled 513,000 hectares and 24,700 hectares in 2018, while respective yields were just 19 and 15 tons per hectare (FAO 2020). Moreover, the targets set for their expansion are far more modest than those set for other food staple and high-value export crops.

These aggregate figures for cassava and potato mask a healthy rate of growth in production, consumption, and use of these crops, especially for cassava. Between 2000 and 2016, the area under cassava cultivation increased from about 237,000 hectares to a peak of 570,000 hectares, while production increased more than eightfold, from around 2 million tons to 11 million tons, indicating a more than doubling of yields that is substantially attributable to the introduction of high-yielding varieties (FAO 2020; Le et al. 2019). In 2016, 70 percent of the country's cassava production was exported in the form of starch or chips for use in processed food, animal feed, pharmaceuticals, and industrial alcohol production (ITC 2018). These exports—88 percent of which were destined for China—generated more than US\$700 million in revenues in that same year.

Potato in Vietnam offers a very different story. Since the mid-1980s, planting has stagnated at the 20,000 hectare mark and production has stalled at about 300,000 tons (FAO 2020). Yet increasing demand from consumers and the food processing industry has led to sizable increases in imports: between 2001 and 2016, potato imports increased 24-fold from 1,574 to 39,700 tons, the vast majority of which originated from China (ITC 2018).

The seed systems for these crops also vary in Vietnam. The cassava seed system is almost entirely informal: Le et al. (2019) found that in 2016, 90 percent of cassava farmers obtained their initial planting material through informal exchanges. The seed potato system relies on more formal sources: in 2016, Vietnam imported 3,650 tons of seed potato from Germany, South Korea, China, the Netherlands, and Canada. A significant share of these imports are likely further multiplied domestically, and additional

but unknown quantities of seed may also come from China in the form of small ware potato that is also used for planting.

For both crops, Vietnam's seed system is governed by laws and regulation that were first formulated in 1996 (Decree No. 07/1996/ND-CP), which focused mainly on varietal improvement, seed quality, and rapid multiplication. The decree establishes that only certified seed may be legally traded and strictly forbids the production and trade of "fake seeds, seeds of poor quality, mixed seeds, seeds with pest or disease germs or seeds which have not been certified" (Article 13, Decree No. 07/1996/ND-CP). Subsequent legislation provides guidance on seed production, quality standards, plant variety protection, and other essential elements of a robust seed system.

Uniquely, in 2008 the Vietnam Ministry of Agriculture and Rural Development (MARD) issued Decision 35/2008/QĐ-BNN, which explicitly permits farmers to collect, store, preserve, use, and distribute local plant varieties and genetic resources, and makes farmers eligible for public financial support for their seed production activities (Tin et al. 2011). Although this decision still prevents farmers from engaging in commercial seed activities, it does provide recognition to the informal seed sector (Lua et al. 2015). Moreover, it implicitly acknowledges that many farmers already engage in what might be described as commercial seed exchanges with fellow farmers at the local level.

Generalizability and Context Specificity

Across all four crop-country combinations, we observe several attributes that are generalizable to all VPCs. First, each country hosts a legal and regulatory framework governing the seed system; a research system that breeds new crop varieties; a public regulatory body that certifies seed; some combination of public and private seed producers; public agencies, public programs, private companies, and other entities that distribute or market seed to farmers; and widespread practices of farmer seed saving, farmer-to-farmer seed exchanges, and seed exchanges in markets. The extent to which this structure caters specifically to VPC seed varies by country and crop.

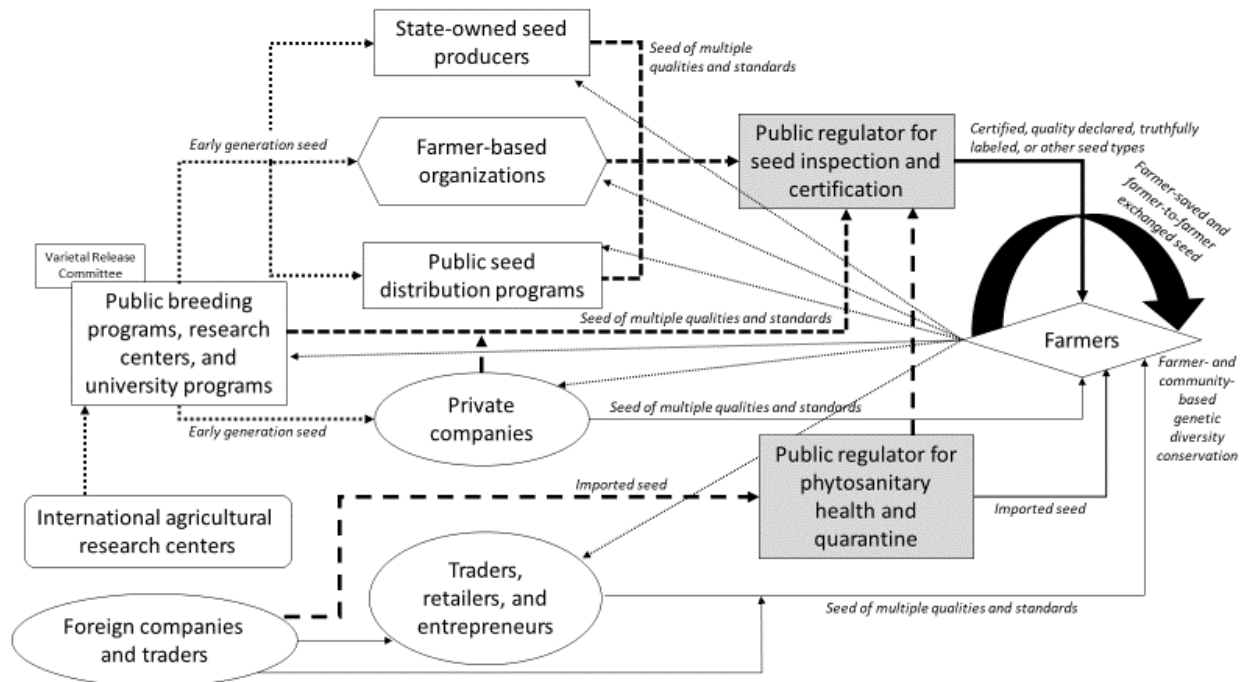
Specifically, variations exist between the selected crop-country combinations in terms of each crop's use and importance to the economy and society; each crop's prominence in the country's economic growth, trade, and agricultural development strategies and policies; the role, authority, and autonomy of the regulatory body; the relative importance of actors involved in varietal improvement, seed production, and seed distribution; the degree of integration between formal and informal seed systems; and the social and cultural practices in production and consumption. Variations also exist in terms of the crop's importance as a traded commodity and the international trade context within which the country operates. We draw on many of these differences in our discussion in the sections that follow.

Figure 1 provides a broad and generalized schematic of how VPC seed systems function, at least for the crops and countries that are the focus of this study. The diagram's complexity highlights the multiple channels through which seed is distributed: through state-owned seed producers, public seed distribution programs, and farmer-based organizations; through domestic and foreign firms; and through traders, retailers, and entrepreneurs of varying sizes and scales. The figure also highlights the many qualities of seed that are distributed through this system, ranging from early-generation seed used in public breeding programs and research centers, to certified or quality-declared seed that is approved by various regulatory agencies (denoted in gray boxes), to seed that is saved and exchanged by farmers themselves. Finally, the figure highlights the diverse contributions of farmers to seed production and use—as contract seed multipliers, as commercial producers in their own right, as conservators of genetic diversity,⁸ and as seed consumers in the system. Taken together, these relationships emphasize the intertwined nature of VPC seed systems and the close interactions between what are often referred to as formal and informal systems (Louwaars, de Boef, and Edeme 2013; Almekinders and Louwaars 2002). Although the actors, functions, and relationships featured in this schematic may not be present in each

⁸ Note that none of our three focal countries are centers of genetic diversity for either cassava or potato. Thus, landraces and genetic diversity conservation may be less central to these seed systems when compared with other countries and crops—for example, potato in Peru, where farmers and communities play a central role in the conservation of potato landraces as part of the wider potato seed system.

crop-country case examined in this study,⁹ the schematic represents a model of a VPC seed system and suggests multiple intervention points through which the system can be influenced or improved.

Figure 1 Generalizable schematic of seed systems for vegetatively propagated crops across the four crop-country combinations



Source: Authors.

Note: Solid lines denote seed used in cultivation. The weight of each line denotes indicative volumes of seed moving through the indicated channel. Large dashed lines indicate regulatory channels, small dotted lines indicate channels for early-generation seed movement, and smaller dotted lines indicate farmer production and supply of seed-to-seed providers.

⁹ Importantly, political economy actors and actor coalitions—including industry, farmer, consumer, and environmental groups that have influence over the design of seed systems policy and regulation—are considered outside the boundaries of this particular schematic. However, their role and influence are addressed in subsequent sections of this paper.

FINDINGS

Our presentation of key findings is organized as follows. First, we provide a basic comparison of VPC seed policies across countries and crops to illustrate the considerable diversity in regulatory approaches to quality assurance. Second, we examine these policies in the context of each country's broader strategic framework for economic growth, agricultural development, food security, and seed market strengthening, with a specific emphasis on the contested narratives around these frameworks. Third, we examine how actor coalitions and networks form around these narratives and advance their interests. Finally, we discuss the potential impact of these actor coalitions, contested narratives, and regulatory diversity on the availability of quality VPC for small-scale, resource-poor farmers in the three focal countries.

Regulatory Diversity and Commonality across Crops and Countries

First and foremost, findings indicate that whereas there are several common features in the regulatory approaches taken to VPC seed quality assurance in the crop-country combinations, the variations are also significant. As a starting point, we observe a common strategy across all crop-country combinations: in the absence of sufficient capacity and effective regulatory systems, breeding programs and research centers themselves are often directly engaged in the production and distribution of quality seed, and often provide support to quality assurance processes in the production of seed by commercial providers. Of course, we recognize that ensuring seed health—specifically, the health of early-generation seed—is a core function of breeding programs and research centers. Because these programs and centers are often the first line of defense against seed- or soilborne pests and diseases, these entities have a keen interest in seed health at all levels of the seed system. However, it may also be the case that large-scale seed production and distribution to farmers lies outside of these organizations' mandate, comparative advantage, technical capacity, and budgetary resources. Such efforts to simultaneously address plant breeding, seed health, and large-scale seed distribution are evident in Nigeria, where there are efforts to breed varieties resistant to CMD and to rapidly distribute stems containing multiple desirable plant

qualities, depending on the source, program, and channel. A similar situation is observed in Vietnam, where the national research system distributes quality (but uncertified) seed potato as well as CMD-resistant cassava varieties, and in Kenya, where the country's potato breeding program is investing in the development and distribution of varieties that are resistant to bacterial wilt, late blight, and PCN.

The second common strategy for providing farmers with quality seed is the promotion of good on-farm management practices for crops and soils, coupled with the promotion of good management practices in the preparation of farmers' own saved seeds and those of small-scale seed production associations and enterprises. This component of an integrated seed health approach (Thomas-Sharma et al. 2017) is best illustrated in seed potato projects in Kenya organized by various national and international organizations, which create and train village-based extension workers and self-help groups in seed potato production. Nigeria uses a similar approach of creating and training village seed entrepreneurs (VSEs) for cassava stem multiplication.¹⁰ Of particular interest is the considerable extent to which government agencies—county agricultural extension services in Kenya and state agricultural development programs in Nigeria—participate in these projects despite regulations that discourage small-scale production of noncertified seed for both crops. The exigencies of market demand and project funding may simply overshadow regulations in such cases, thereby providing tacit state recognition of the informal VPC seed system. But the cost-effectiveness and sustainability of this strategy remain to be seen.

A third strategy employed is the practice of quarantining, destroying, or otherwise removing crops deemed to be acutely infected by pests or diseases. In Vietnam, where this practice is observed most significantly, the government's primary regulatory instrument is reactive: monitoring pest and disease outbreaks, destroying infected and quarantined cropland, and continued monitoring after outbreaks or proliferations of suspicious seed lots. Such was the strategy taken in response to the CMD outbreak noted above and to ware potatoes imported from China and used as seed but thought to be of low or unknown

¹⁰ In Kenya, partners in these types of projects include the International Potato Center (CIP), the Syngenta Foundation for Sustainable Agriculture, Farm Input Promotions Africa Ltd., and Kisima Farm Ltd., among others. In Nigeria, partners include IITA, Catholic Relief Services, and the Justice, Development, and Peace Commission, among others.

quality.¹¹ While these strategies—especially Vietnam’s strategy—bear low administrative costs, their broader economic and social consequences may be nontrivial.

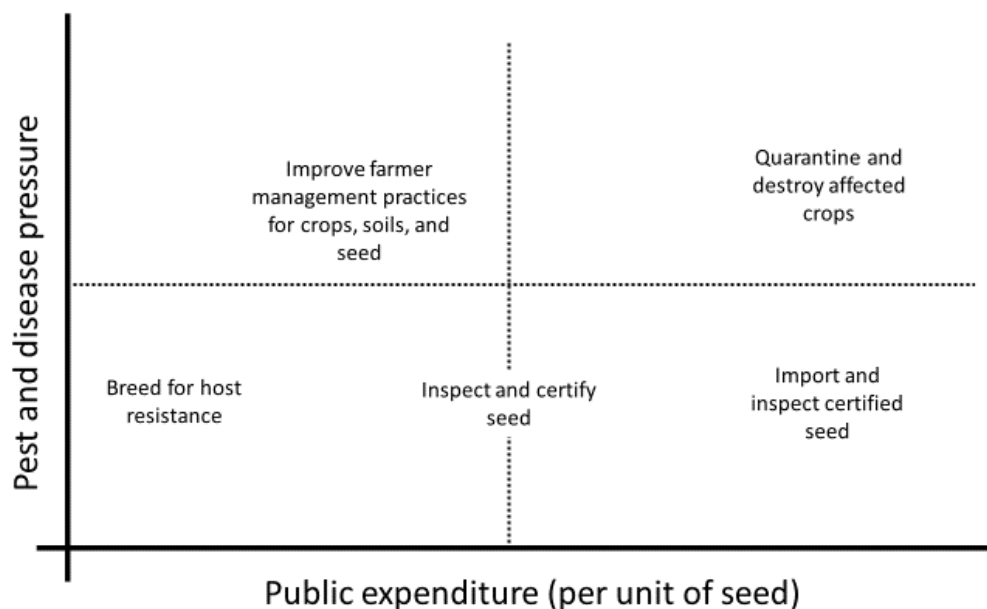
A fourth strategy is illustrated by Vietnam’s approach to seed potato, a strategy that is also being pursued in Kenya. Vietnam relies extensively on imports of certified seed potato from European and other countries where high-quality material is commercially available, particularly for varieties used in the food processing industry. In effect, Vietnam recognizes its comparative disadvantage in seed potato production, and relies instead on trade with Europe to provide quality seed potato to farmers, going as far as to subsidize these imports for farmers. Although this strategy does not preclude the importation of noncertified or substandard materials through other channels (e.g., the cross-border trade in ware potato with China that also provides an implicit supply of seed potato) or public- and private-sector efforts to improve the quality of domestic seed production, it does place an emphasis on quality assurance. Kenya, which similarly imports certified seed from Europe, has occasionally taken the opposite approach, rejecting the quality assurances provided by the European seed potato producers.

A fifth strategy employed by all countries is the formal inspection and certification of seed. Among the three countries studied here, Kenya has what is arguably the most effective seed regulator: KEPHIS. Yet even KEPHIS’s capacity to monitor, inspect, and certify seed production is limited when it comes to VPCs. At present, its operations related to seed potato are limited to inspection of the state-owned ADC and a small number of private companies. KEPHIS has neither the resources nor the personnel to monitor and inspect small-scale seed potato producers, even with the recent decentralization of inspection offices in major ware production areas and with the use of private, accredited inspectors. However, in effect, KEPHIS’s focus is still limited to the formal seed potato sector, representing just 4–5 percent of the total market.

¹¹ In Kenya, KEPHIS has employed similar practices as part of its formal inspection and certification system, which more closely aligns to the fifth strategy listed below. KEPHIS’s practices include the rejection and destruction of seed potato lots on seed providers’ production facilities or, for imported seed, at port. Such seed potato has also been sold in Kenya as ware in geographies where potato is not cultivated.

Overall, we find that each seed quality assurance strategy described above is associated with some cost, whether measured in terms of public expenditure on research, extension, and regulation, or in terms of social and economic value. In Figure 2, we provide a stylized mapping of each strategy to supply quality seed and combat pest and disease pressures against the notional public expenditure requirements in the short to medium term. On the cost side, we consider that both phytosanitary inspection of seed imports and the quarantining and destruction of affected standing crops incur a lower cost than breeding programs for host resistance and extension programs to improve farmer management practices. That said, it may be the case that breeding for host resistance and extension services are actually lower-cost and higher-return investments than inspections and quarantining, particularly when considered in terms of per-unit cost (i.e., the cost per unit of seed distributed or area planted).

Figure 2. A stylized mapping of VPC seed quality assurance systems against pest and disease pressures and public expenditure requirements



Source: Authors.

We also consider strategies in terms of their capacity to address pest and disease pressures. Although certified seed imported from countries with highly effective regulatory systems might seem like a means of combating pest and disease pressures, experiences with seed potato imported by Kenya and

Vietnam may suggest the opposite (i.e., pathogens may have been introduced through these import channels). This issue indicates some ambiguity—or a lack of coordination—in how countries deal with imported and domestically certified seed with respect to pest and disease management. Drawing on the historical record for cassava, we also consider breeding to be among the more effective approaches to controlling pest and disease resistance. This assessment may be especially true if we expand the definition of breeding to include research more broadly, thereby encompassing the biological control systems developed to contain mealybugs, a pernicious pest that causes serious damage to cassava (Nweke 2010).

Furthermore, it may often be the case that that these strategies may be close substitutes or complements, implying both trade-offs and synergies. For instance, it is possible that a strategy focused on breeding for host resistance can render a strong inspection and certification strategy less necessary and more costly, indicating that the two strategies are near substitutes.¹² Similarly, it is possible that investing in improved crop management among farmers works best when combined with farmers’ use of certified seed, indicating complementarities. These trade-offs and synergies have further implications for pressures related to cost and those involving the rate of pest and disease occurrence.

Relatedly, we find that no single country employs one strategy exclusively. Kenya, for example, manages a research system and regulatory body that together demonstrate a potential strategy to supply quality seed potato and manage pest and disease pressures, albeit only within the formal commercial market at the moment. Nigeria’s research system, state extension programs, development projects, and government initiatives have historically shown impressive impacts and may hold even greater potential at scale in the future. Vietnam’s “quarantine and destroy” strategy, while possibly quite draconian, is offset, in the case of potato, by European imports of quality seed potato. In sum, seed quality assurance systems for VPC crops cannot rely exclusively on regulation; public investment in research and extension, accommodating trade policies, and active surveillance of plant health may all have an additional role to

¹² As pointed out by several reviewers, host resistance may vary across varieties of a specific crop, resulting in the continued need for an inspection and certification system, especially where such systems also prioritize assessments of trueness to type and other important factors.

play. And in the case of VPCs, some combination of these latter strategies may actually play a more important role than a strict regulatory system itself.

Finally, we find that these strategies are, in general, highly derivative of strategies designed for seed quality assurance in cereals and the pest and disease threats to cereals. For example, a close reading of the amendments to Kenya's seed regulatory framework since 2010 indicates that changes were drawn from requirements for maize, for which production can be more readily centralized and where interseasonal storage is less of an issue than it is with VPCs. As a result, the language often refers to seed lots, germination tests, inspection frequency, and sampling schemes that are appropriate for maize and other cereals but less so for potato and other VPCs. Similarly, references to the number of allowable generations from breeder to certified seed that can be multiplied are drawn from standard practices for hybrid maize, where a small number of generations between breeder and certified seed is desirable. This practice is inapplicable to potato, which is clonally propagated and thus less prone to genetic erosion, and also has a low multiplication rate that restricts the number of generations allowed in a seed class and thus reduces the profitability of seed production. On the implementation side of these seed regulations, there are reports of arduous and costly procedures and long delays for registration and inspection, coupled with limited capacity of the seed regulators, who are more familiar with the seed production, varieties, and pest and disease characteristics of cereal crops. These realities tend to discourage potential entrants, especially smallholder seed producers, and pose challenges for seed inspection and certification.

Competing Narratives and Diverse Actor Coalitions

In several of the crop-country combinations, findings suggest the coexistence of competing narratives on the role of policy and regulation in VPC seed system development. While it may be difficult to assess the relative power or weight of these competing narratives given biases in data collected from KIIs and FGDs, we illustrate the key framings and actor coalitions behind these narratives in our four crop-country combinations.

The primary narrative across all three countries is what we describe as the “food security first” framing. In Kenya, for example, the current overarching strategy for economic growth (the Big Four Agenda) and agricultural development (the ASTGS) approach seed primarily through a food security lens. This focus means prioritizing seed policies, regulations, and investments that close yield gaps, increase crop production, and reduce food prices to ensure affordable subsistence for the country’s growing population. As a result, many of the line ministries and agencies directly involved in agriculture view seed systems development through a similar lens, believing that seed systems exist to provide farmers with affordable access to improved varieties and quality planting material. Such was the general reflection from key informants affiliated with county governments (both administrative and extension staff), and the federal Ministry of Agriculture, Livestock, and Fisheries (MoALF). The narrative is similar in Nigeria but far less so in Vietnam, given that neither cassava nor potato is considered food a security crop.

The punchline of this narrative is that short-term increases in the supply of the highest seed quality possible to increase food production outweigh longer-term improvements in seed market functioning, rural enterprise development, and regulation. By extension, this narrative rationalizes public investment in seed production and distribution programs and state-owned enterprises, while catering to the short time horizons under which political leaders often operate and their preference for observable results within these short horizons.

The opposing narrative common to all three countries might be termed the “regulator first” or “pest- and disease-risk mitigation first” framing. Its underlying narrative emphasizes the need to prevent seed producers and retailers from providing farmers with seed of a low or unknown quality level. Thus, it may be more accurately framed as the need to regulate quality more effectively, without reference to malfeasance. In Kenya, for example, several key informants affiliated with research, regulation, private investment, and certain donor-funded projects argued that only certified seed potato could prevent the spread of pests and disease to protect national potato production and yields.¹³ But supporters of this

¹³ While this view is sometimes framed as the need to control the proliferation of counterfeit or fraudulent seed in the market, there is little evidence to suggest rent-seeking behavior of this nature in the markets for VPC seed in the focal countries.

narrative do not recognize that the demand for seed from the farmers far exceeds the regulatory capacity of the countries to inspect and approve seed for sale as certified in sufficient quantities. Insufficient quantities of certified seed may raise seed prices to rates that are not affordable to small-scale farmers or may cause farmers to rely on their saved seed as planting material, which contributes to the problem of pest and disease, ultimately affecting potato production and yields.

A “private investment” framing suggests that the design and enforcement of quality assurance regulations is essential to encouraging private investment in each country’s seed market. In Kenya, the framing splits between “foreign private investment” and “domestic private investment.” The former is characterized by foreign firms seeking plant variety protections and easy navigation through phytosanitary inspections and quarantines for imported seed or seeking inputs for vertically integrated production systems (e.g., potatoes for chips and fries in their food outlets). The latter is characterized by domestic firms seeking more effective and lower-cost inspection and certification procedures and, in certain instances, infant industry protections from foreign competition, as well as firms in agroprocessing with varying degrees of vertical integration.

Yet another narrative is what we might describe as the “grassroots projects” framing, which is closely related to the “food security framing” discussed earlier. Its underlying narrative holds that noncertified, farmer-managed production of clean seed is a feasible standard to promote, that pragmatic and decentralized alternatives to a strict regulatory system exist, and that yield gains will contribute to improvements in rural livelihoods over a longer time period than policymakers or regulators may be willing to accommodate. Again, the VSE model of cassava seed production in Nigeria and the village-based advisors and self-help groups for seed potato production in Kenya are useful examples. Their approach hinges on investments in technical capacity and strong self-regulation norms to encourage the growth of localized VPC seed systems and markets.

In each country, the actor coalitions and networks that subscribe to these framings are fluid, as is the distribution of power among them. Several findings emerge from our observations and analysis. First, in both Kenya and Vietnam, there is a strong coalition around private investment in their respective seed

sectors, advanced by a coalition of both foreign and domestic interests and policymakers. The revisions to Kenya's seed regulatory framework since 2010 illustrate this coalition, with an almost exclusive focus on increasing foreign and domestic private investment in Kenya's seed sector (Munyi and De Jonge 2015).

Yet these coalitions are themselves fairly tenuous. With respect to potato in Kenya, we observe bilateral development agencies supporting their private-sector counterparts to advance plant variety protection legislation and guidelines, to strengthen the regulatory standards and capacities, and to increase the availability of varieties and seed for potatoes used in processing and food retailing. Not surprisingly, neither coalition exhibits much interest in the efficiencies associated with competitive markets; rather, each is aiming to secure market power through favorable policy and regulation, often pitted against those organizations dedicated to developing more local, farmer-based seed systems.

Moreover, there are significant absences in these coalitions, reflecting little of the growing body of theory and evidence suggesting that technological change at the farm level will be driven by demand from actors further along the value chain (Reardon and Timmer 2012). For example, in the case of cassava in Vietnam, we see little evidence of a role played by starch factories in the provision of either improved varieties or quality seed to farmers that supply their feedstock. Similarly, in Nigeria, we see little evidence that enterprise development initiatives meant to increase cassava's use in processing and food preparation have had much influence on either varietal change or seed quality assurance systems. This lack of influence may reflect any number of factors, such as the rudimentary nature or nascent development of these industries; one might argue that neither industrial starch factories nor *gari* processors are particularly discerning about the quality of their feedstock. Or it might reflect a strongly segmented market in which value chain actors have little influence on seed quality among smallholders because smallholders cultivate varieties that are preferred for home consumption but not valued by processing or food retail operations. Or it may simply be that either the varieties in use are resistant to major pathogens affecting seed or the pathogens are not particularly problematic to farmers or other value chain actors.

We also observe that government actors—policymakers, public researchers, and regulators—do not necessarily play the role of “benevolent social planners” or present themselves as a single-actor coalition. In each crop-country combination, government actors subscribe to one or several of the framings above and participate in coalitions to advance the associated narrative. The divergence between policy actors and regulators is observed in the case of Kenya. In Nigeria, the case is less clear: regulators seem to take a more pragmatic perspective on seed system development—acknowledging that regulation of the entire cassava seed system is a Sisyphean task—that falls closely in line with the views of policy actors. Meanwhile, in Vietnam, there is little sense of any discord among government actors.

Last, we observe that national advocacy groups—seed trade and crop grower associations—play a relatively limited role in these coalitions. In some instances, they are merely extensions of government or donor interests. In other cases, they represent just a subset of private-sector interests (foreign or domestic). And rarely do these groups provide effective representation of farmers themselves, whether as producers of seed or of crops. That said, in the case of Kenya we do observe a fairly active set of such groups playing an advocacy role within one of the many coalitions described above, several of which are constructively contributing to the design and formulation of seed regulations through various stakeholder engagements. But we see little leadership from the national research organizations and policy think tanks in providing data and analysis that might contribute to these debates and guide VPC seed regulatory reform—with the possible exception of Kenya, where several domestic and foreign organizations actively engage.

Drivers of Change: Organization, Technology, Trade, and Crisis

Extending this analysis of competing narratives and actor coalitions, we identify here several key drivers of policy and regulatory change for the crop-country combinations examined in this study. First, we examine several institutional factors and organizational innovations that are affecting policy, regulation, and ultimately, the potential for VPC seed market growth. Second, we highlight several technological opportunities that may drive similar outcomes, followed by emerging market and trade factors affecting

policy, regulation, and market growth potential. Finally, we explore the effect of crisis and related responses on these same outcomes.

From an institutional and organizational perspective, the one significant factor observed in Kenya, Nigeria, and Vietnam is the role of the state and, specifically, the state's regulatory apparatus. Although KEPHIS in Kenya, NASC in Nigeria, and MARD in Vietnam operate quite differently—each with its own level of independence, autonomy, coverage, and technical capacity—they embody the strength of the state's regulatory powers. The rules, guidelines, and procedures that they are charged with executing play a fundamentally important role in shaping the market for VPC planting material. This authority has allowed them to introduce several simple innovations with potentially far-reaching consequences for regulation. For example, KEPHIS has been able to adapt its regulatory infrastructure to the constitutional devolution of administrative powers to the county level, allowing the regulator to extend its reach and support county-led initiatives in seed production and distribution. KEPHIS is also implementing the use of accredited private seed inspectors, with the first rounds of inspectors drawn from existing seed companies and trained to operate their companies' internal quality assurance practices in compliance with KEPHIS's standards and guidelines.¹⁴ The use of accredited private seed inspectors can potentially extend the reach of inspection agencies that are hobbled by limited personnel and infrastructure, although concerns remain about the potential for rent-seeking behavior in the absence of sufficient monitoring and oversight by these inspectors.

On the technological front, efforts in Kenya to develop and scale the use of new seed production systems—advanced rapid propagation techniques such as the use of aeroponic systems for the production of mini-tubers and using transplanted tissue culture plantlets to produce rooted apical cuttings—are transforming the commercial viability of the certified seed potato industry and requiring regulators to adapt their regulations and guidelines to recognize these new technologies (Demo et al. 2015; Parker 2019; Parker et al. 2019). In Nigeria, NASC's Cassava Seed Tracker, developed by IITA, provides

¹⁴ Future applications of this approach may allow accredited inspectors to provide services independently and commercially.

regulators and seed producers with an app to better coordinate seed production, inspection, and certification. Across all countries, key informants noted that low-cost field disease diagnostic kits may be poised to improve the accuracy and timeliness of inspection procedures. The effectiveness of these technologies has yet to be evaluated in terms of their impact on market size, seed product quality, on-farm productivity, or social and economic outcomes for smallholder farmers, but the impact pathways indicate considerable potential.

Meanwhile, trade considerations are also driving change. Regional harmonization of seed regulations in eastern and southern Africa under the Common Market for Eastern and Southern Africa (COMESA) and in western and central Africa under the Economic Community of West African States (ECOWAS) offer Kenya and Nigeria—two of the largest economies in these regions—opportunities to expand their VPC seed products into neighboring countries, subject to the application of a well-defined quality assurance system. Vietnam, as a full-fledged member of the World Trade Organization and a keenly export-oriented economy, is also cognizant of trade considerations in seed-sector development—although those concerns seem to revolve more around phytosanitary standards for imported seed, given that Vietnam does not prioritize either cassava or potato seed as potential export commodities. Still, compliance with the global trade regimes governing the seed industry—and, in particular, membership in the International Union for the Protection of New Varieties of Plants—is a significant element of Vietnam’s outlook on seed system policy.

Interestingly, and as discussed above, we observe a marginal role played by industry and demand-side factors as a driver of more effective VPC seed quality regulation. For example, one might expect fast-food retailers in Kenya and Vietnam to have an outsized influence on policy by demanding a regulatory system that ensures a steady supply of quality planting material for varieties specifically adapted to potato chip production. While that channel of influence does exist, its pressure on the regulatory system—as opposed to the varietal registration and release system—seems to be nominal. In other words, neither KEPHIS nor the wider potato production system in Kenya has reoriented itself to this “demand-pull” effect because it remains a relatively small niche in the larger market for potato. An even

more obvious illustration of the absence of this effect is observed in Vietnam, where cassava starch factories play no role in providing farmers with either quality stems or improved cassava varieties to accommodate their specific feedstock requirements.

The single most common driver observed in the crop-country combinations covered by this study is crisis. The outbreak of a significant pest or disease threat tends to marshal significant regulatory responses. In Kenya, these threats are illustrated by the spread of bacterial wilt and PCN for potato; in Vietnam, by an outbreak of CMD for cassava and the spread of poor-quality imported potato used for seed; and in Nigeria, by the persistence (as opposed to an outbreak) of CMD. In each country, these threats have led to different responses. Vietnam pursued the “quarantine and destroy” strategy described earlier. Kenya doubled down on its zero-tolerance thresholds for infected planting material that was produced domestically or imported from Europe, much to the chagrin of private-sector seed producers and with little impact on the informal seed production system.

Nigeria’s response to its ongoing crisis is slightly different: pragmatism. Given the seemingly intractable challenges of regulating a seed sector that easily reverts to an unregulated state, seed system actors in Nigeria have prioritized other crops, markets, and administrative issues, allocating quality assurance systems for cassava seed to the remit of researchers, technologists, and entrepreneurs, even in the presence of major cassava productivity initiatives by the government. This pragmatism is also implicit in the other crop-country combinations, where there exists a tolerance for—and even active support of—informal seed systems. After all, maize in Kenya and rice in Vietnam are likely higher-order issues for most actors in the agriculture sector, whereas Nigeria has sufficient diversity in its agricultural sector to readily divert attention away from issues of cassava seed quality assurance.

That is not to say that cassava or potato seed systems escape regulatory scrutiny entirely. In Kenya, public regulators and administrators at multiple levels have learned valuable lessons about how to control the proliferation of low-quality or fraudulent seed from past experiences in the maize seed sector, and they seem keen to apply those lessons to other crops and markets. And in both Kenya and Nigeria, the pressures emanating from the regional harmonization of seed regulations and regional trade integration

may cause these same regulators and administrators to move from rhetoric to action in the case of cassava and potato. Taken together, these trends suggest that VPC seed regulations are being shaped by regulators' prior experience with cereal crops and trade concerns, with little recognition of the crop-specific nature of seed systems and the possibilities for the coexistence of different systems and potentially transformative technological solutions.

DISCUSSION AND POLICY OPTIONS

Given the findings above, what are the options for improving policy and regulation for quality VPC planting material? We preface this discussion with a few important caveats. First, each crop and its seed system is context-specific, so options that might work in one market, agroecology, or country may need to be radically adapted to fit the needs of another. For this reason, we offer options below that draw on broad, shared principles but also require considerable adaptation to context. Second, policy and regulatory reforms are not necessarily win-win solutions: gains for one actor in a seed system may come at the expenses of others. With this in mind, the options we propose below focus on the simple proposition that the benefits from the current seed systems in the crop-country combinations covered in this study are extremely limited, and that any expansion in market size will be generally welfare-improving, with a bias toward smallholder farmers. Third, policy-change processes require political will, which is itself a function of the way actor coalitions compete or cooperate in the policy and regulatory space. We have described those forces in our findings and recognize that they are a strong undercurrent in the success or failure of the policy, regulatory, and investment options explored below.

The main question raised by our findings is as follows: What type of policy and regulation is required for VPC seed quality assurance? We argue that a strict certification regime that mirrors cereal seed certification regimes is simply unfeasible for VPCs. We also argue that the same applies *among* VPC crops: some VPC varieties (e.g., seed potato in Kenya) offer farmers genetic gains or market value or both, whereas others (e.g., cassava in Nigeria) offer only occasional genetic improvements and limited market value. This variability suggests the need for crop- and context-specific policy and regulation for seed quality assurance.

We observe very little articulation of demand for quality seed from farmers, industry, or consumers, and limited capacity to supply regulatory services—either by an external public regulator or by practices internal to the firm or producer—in the fragmented markets for VPC seed. This does not imply that there is no demand for quality seed among farmers in developing countries or that developing

countries should dispense with VPC seed regulations. Rather, it suggests that scarce public resources should be concentrated where they can have the most significant impact on seed quality. We outline several options below that highlight a suite of policy, regulatory, market, and technological recommendations, summarized in Table 4. Although our list does not rank these options per se, it does focus first on policy and regulatory recommendations—options that are more directly related to the aim of this study—followed by market and technology recommendations.

At the broadest, most general level, our findings suggest that national policies and directives need to walk back the marginalization of informal VPC seed systems, including their criminalization of non-certified VPC seed production and the strict demarcation of who can produce and distribute VPC seed. A more progressive policy regime that recognizes these informal seed systems and acknowledges the need to professionalize them with technical and financial support—rather than to replace or eliminate them—provides further policy guidance that retreats from the rhetoric of the more contested and controversial framings and narratives described earlier. Of course, these recommendations are cosmetic at best: changes to the language in policy documents may be merely a *de jure* remedy that ultimately may have little bearing on *de facto* seed systems. But it may create a more permissive environment for public investment and regulation, and it may support the development of VPC seed markets.

Table 4. Policy, regulatory, market, and technological options for VPC seed system development

Recommended option	Description
Reform language in national policy on seed systems and markets	Legalize informal VPC seed production and withdraw language that criminalizes informal VPC seed production and trade, where relevant; recognize informal seed production and trade as extant systems that require public and private support, not elimination or replacement.
Prioritize public investment in early-generation seed production	Concentrate public spending on the production and distribution of high-quality early-generation seed in research centers, state-owned enterprises, government development programs, or through public-private partnership arrangements.
Introduce multiple or alternative seed quality categories	Introduce quality-declared seed or similar categories, along with related standards and protocols for rural entrepreneurs and farmer-based organizations, to complement existing classes of early-generation seed.
Decentralize regulation to local levels	Pursue approaches that combine internal (producer-level) quality assurance systems with decentralized external regulatory oversight to accommodate the unique biological aspects of VPC seed.
Increase use of accredited third-party quality assurance services	Use accredited third-party inspection services, facilities, and inspectors or internal (firm-level) quality assurance systems to increase the coverage of regulatory oversight, given the need for decentralized regulation and limits on public resources.
Invest in the development and use of seed traceability systems	Invest public and private-sector resources in the design, testing, and application of seed traceability systems that track material from source to field, and possibly allow for monitoring of varietal adoption, quality seed use, and pest and disease susceptibilities.
Harmonize national policy and regulation with regional and global standards	Update national policy and regulations to align with commitments made under regional and global agreements on policy and regulatory harmonization of seed trade, with specific reference to VPCs.
Provide subsidies to incentivize production, marketing, and use of quality seed	Design and implement targeted subsidy programs that support seed producers, distributors, and/or farmers as a means of lowering costs and encouraging production and use of quality seed.
Develop capacity of rural entrepreneurs and farmer-based organizations	Develop capacity of entrepreneurs and farmer-based organizations through technical training, business services, and other support to produce, brand, and distribute seed in localized markets using high-quality, early-generation seed; develop internal quality assurance practices and protocols.
Strengthen risk assessment and communication for VPCs	Develop more effective, farmer-facing tools to assess and communicate the technical, social, and economic risks of biotic and abiotic threats to VPC production and the contribution of quality seed to mitigating these risks.
Invest public resources in breeding for host resistance	Invest public resources in breeding programs that focus on host resistance, especially for intractable seed-borne pests and diseases.

Source: Authors.

In terms of public investment prioritization, our findings suggest that greater public resources could be concentrated in strengthening quality control and quality assurance for early-generation seed production (i.e., in the seed classes that are produced by research centers, private firms, and NGOs as an input to the production of subsequent-generation seed that is ultimately sold to farmers). These classes include mini-tubers and rooted apical cuttings produced using more cost-effective rapid multiplication technologies that reduce the number of generations needed before seed is sold to farmers. This approach does not eliminate pest and disease threats with a zero-tolerance threshold, but it does potentially reduce such threats. It also requires considerable investment—both public and private—in traceability systems for seed, multiple or complementary seed quality categories, good seed production practices, and associated technologies. Importantly, the approach increases the space in which farmers, farmer organizations, and other actors can become producers of seed of greater quality than what they might otherwise produce using their own material. It is a pragmatic option that may dissatisfy some pathologists and regulators, but it recognizes the limitations of both formal and informal seed systems. What warrants further attention in this approach is the investment in traceability systems for seed, multiple seed quality categories, and good seed production practices. We explore each of these elements below.

Traceability potentially allows for supply-chain actors—breeders, multipliers, distributors, transporters, retailers, and regulators—to track seed back to its source, isolate points along the supply chain where pest and disease threats might have emerged, and take remedial action to address these threats. Traceability systems may also allow for the monitoring of varietal adoption and quality seed use—an important but still elusive means of measuring the impact of public investment in agricultural research and extension (Wossen et al. 2019; Kosmowski et al. 2019; Floro et al. 2017; Bold et al. 2017; Maredia et al. 2016; Rabbi et al. 2015). Traceability systems range from simple paper-based tagging systems that designate origin, source, or permissible distribution areas, to more sophisticated tools such as NASC’s Cassava Seed Tracker or blockchain technologies. There are, however, potential limits on traceability when the purchase of planting material through formal channels (where traceability systems are installed) happens infrequently due to low replacement rates.

In addition, these traceability systems are only as good as the seed producers that manage them. And for many VPCs, those seed producers are likely to be farmers or farmer-based organizations serving their immediate localities, given the bulkiness and perishability of most VPC seed. Greater investment in developing the capacity of seed entrepreneurs and farmer-based organizations may be the most important investment that can be made to accelerate the growth of VPC seed markets serving the needs of smallholder farmers. These capacity needs include training in seed production, identification and management of pests and diseases, and proper storage and packaging of seed, as well as business skill and enterprise development. Such capacity development efforts may be complemented by targeted subsidy programs designed to lower the costs of production for these types of seed producers, improve the viability of commercial seed distribution networks, or encourage farmer uptake of quality seed. Note, however, that past experience with both producer and consumer (farmer) subsidy programs for seed system development has been ambiguous at best, with mixed records of success across both crops and countries. There are many examples of capacity development projects and subsidy programs in this vein, several of which have been described above. But their success ultimately relies on the signal associated with their products. And this is where multiple quality standards play an important role in providing information to farmers and creating trust and reputational integrity for these producers over the long term. Multiple standards imply a combination of internal quality assurance practices; branding, packaging, and labeling by the producer itself; and signals of external quality assurance such as quality-declared or quality-assured seed tags that indicate compliance with a more farmer-appropriate standard than certified seed standards. (See FAO [2010] for protocols and standards for quality-declared planting material for VPCs.) In several of the crop-country combinations covered in this study, the absence of multiple standards—indeed, the illegality of certain standards and practices—suggests significant opportunity for policy reform.

Importantly, the introduction of multiple classes or categories reduces entry barriers to the VPC seed market and allows seed producers to pursue marketing strategies such as product differentiation and price discrimination. These factors, in turn, may encourage growth in the market for VPC seed and the

markets for specific niches, including specific farmer typologies, agroecologies, and product attributes. Necessarily, this outcome hinges on sufficient supply of early-generation seed, regulatory capacity to certify this seed, and investment in farmer entrepreneurs and farmer-based organizations.

This strategy of introducing multiple seed categories—and thus encouraging the growth and expansion of VPC seed markets for smallholders—is partly built on the acceleration of varietal turnover. In many smallholder systems, demand for fresh seed will remain inextricably linked to demand for a new variety embodying new biotic and abiotic resistance traits, processing or consumption qualities, or other characteristics. Globally, varietal turnover is generally slow among clonal crops such as potato and cassava, and farmers may simply not be looking for new seed unless they are looking for new varieties with preferred traits. A continuous stream of new and improved varieties distributed as quality seed may be a more marketable product than simply quality seed of the same variety. But while this approach has merits, if the phytosanitary quality of VPC seed deteriorates faster than its genetic quality, then the acceleration of varietal turnover is unlikely to be a practical first-order strategy.¹⁵ Where low varietal turnover rates and unanticipated biotic stresses are common, a more viable strategy may be a combination of promoting quality seed management practices to farmers and supplying disease-free seed for periodic replacement.

Given that the introduction of multiple seed categories is only as good as its implementation, our findings suggest a need for greater devolution and decentralization of regulatory processes to the local level. In effect, this means combining the internal quality assurance systems of the seed entrepreneur or farmer-based organization with both (1) an external oversight or audit function by the regulatory body, representing the supportive function (or credible threat) of external inspection of fields, plants, packaging, or records that limits rent-seeking behavior, and (2) technical support, training, and communication from those same bodies in building organizational capacity to meet regulatory expectations. Given the localized and dispersed nature of VPC seed markets, this requires some degree of decentralization of the public

¹⁵ For an informative discussion of the role of seed systems in accelerating varietal turnover in roots, tubers, and bananas, see Thiele and colleagues (2021).

regulatory apparatus or accreditation of private or public local administrators mandated with oversight of agricultural development activities and programs.

This strategy and its associated outcomes hinge on investment in better mechanisms to assess, revise, and communicate risk to farmers and other seed system actors. New and emerging pests and diseases are a constant threat to VPCs, and responses to those threats can be coordinated only through a well-integrated seed quality assurance system. The system described above attempts to provide such integration by professionalizing the seed system—in effect, formalizing the informal system while simultaneously informalizing the formal system.¹⁶ However, an integrated system also requires, *inter alia*, more effective procedures for identifying both local and transboundary threats in a timely manner; better risk assessment standards that are strictly based on science and not simply on zero-tolerance thresholds for every threat; greater capacity to conduct risk assessments, including assessments of social and economic risk; and better methods to communicate risk beyond technical experts—to farmers, farmer-based organizations, consumers, and other seed system actors.

We also note that there are potential gains to be made from engaging in regional and global agreements that seek to harmonize seed quality regulations and encourage trade in quality seed. This topic is already the focus of regional efforts among COMESA and ECOWAS member states, although progress has been mixed on revising domestic policy and regulation to bring them in line with the harmonization efforts. The gains from trade are potentially significant, ranging from new market opportunities for seed producers to greater competition in seed markets that lead to lower prices and more rapid technological innovation. For VPCs, however, the success of harmonization will depend acutely on whether multiple seed categories are introduced, whether traceability systems are put into place, and whether many of the other recommended options discussed above are addressed.

Finally, these strategies are all contingent on continued public expenditure on breeding for host resistance to seedborne pathogens and the production and distribution of early-generation VPC seed.

¹⁶ With thanks to Ahsan Rana (2010) for his first use of this analogy.

Ideally, these investments should be constants in VPC seed systems development.

None of the policy and regulatory options presented here are immediate, short-term panaceas to the pervasive challenge of VPC seed system development. They require long-term investments in programs and projects that put smallholder farmers at the center of a change process while also challenging actor coalitions that have a stake in the status quo. But if the status quo is relevant to such a small share of the VPC seed system at present—as shown in the crop-country cases covered in this study—then there should be scope for considering such options.

CONCLUSIONS

Efforts to build effective quality assurance systems for VPC seed are challenged by the fundamental nature of VPC seeds and seed markets in many developing countries. Binding constraints include not only biological characteristics such as perishability, bulkiness, low multiplication rates, and high rates of pest and disease accumulation, but also economic characteristics: market frictions such as highly localized, dispersed, and fragmented market structures and the nonappropriability of gains from innovation in these markets. To date, few developing countries have invested sufficient public resources in designing regulatory systems that are cognizant of these constraints and tailored to the characteristics of each crop and the context in which farmers cultivate these crops. These restrictions are illustrated by the four crop-country combinations examined in this study.

Our findings demonstrate that the status quo in terms of seed production, distribution, and regulation is untenable: state-led production systems and programs combined with strict, centralized regulatory regimes necessarily limit market size and reach, thereby limiting smallholder farmers' access to both new genetics and quality seed. This status quo neither provides credible oversight or direction to VPC seed systems nor addresses the needs or preferences of farmers, whether or not they are well-articulated through market or nonmarket mechanisms. Solutions require longer-term strategies that rely not only on technological fixes such as advanced propagation systems and seed tracking apps, but also on a policy and regulatory environment that explicitly encourages the coexistence of multiple seed quality categories and the integration of multiple seed production and marketing systems.

We recommend a set of public policy, investment, and regulatory reforms that

- recognize extant seed systems and end the marginalization or criminalization of informal seed production and trade;
- prioritize public investment in early-generation seed production, distribution, and traceability systems;

- invest in capacity development for rural entrepreneurs and farmer-based organizations in VPC seed production and marketing;
- introduce multiple or alternate seed quality categories such as quality-declared seed along with decentralization of quality assurance systems that combine internal systems with external oversight or the threat of such oversight; and
- improve assessment and communication of risk associated with biotic and abiotic threats to VPCs that may be mitigated through the use of quality seed and improved genetics.

Many of the elements in these policy, investment, and regulatory reforms are, in fact, observed in this study's crop-country combinations or are common features of VPC seed systems in other countries with more mature seed markets. Yet in many developing countries, there remains a tension between specific actor coalitions with implicit interests in how one or more of these elements evolve. In other words, there are winners and losers in policy-change processes, and explicit recognition of the expected gains and losses to these groups is an essential part of the process.

REFERENCES

- Akerlof, G. 1970. "The Market for Lemons: Qualitative Uncertainty and the Market Mechanism." *Quarterly Journal of Economics* 84 (3): 488–500.
- Alene, A. D., M. Khonje, T. Abdoulaye, P. Kulakow, and V. M. Manyong. 2012. *Adoption of Improved Cassava Varieties in Southwestern Nigeria*. Diffusion and Impact of Improved Varieties in Africa (DIIVA) Project Technical Report. Ibadan, Nigeria: International Institute of Tropical Agriculture.
- Almekinders, C. J. M., and N. P. Louwaars. 2002. "The Importance of the Farmers' Seed Systems in a Functional National Seed Sector." *Journal of New Seeds* 4 (1-2): 15–33.
- Almekinders, C. J. M., S. Walsh, K. S. Jacobsen, J. L. Andrade-Piedra, M. A. McEwan, S. de Haan, L. Kumar, and C. Staver. 2019. "Why Interventions in the Seed Systems of Roots, Tubers and Bananas Crops Do Not Reach their Full Potential." *Food Security* 11: 23–42.
- Asante-Pok A., 2013. *Analysis of Incentives and Disincentives for Cassava in Nigeria*. Monitoring African Food and Agricultural Policies Project (MAFAP) Technical Notes Series. Rome: Food and Agriculture Organization of the United Nations.
- Bold, T., K. C. Kaizzi, J. Svensson, and D. Yanagizawa-Drott. 2017. "Lemon Technologies and Adoption: Measurement, Theory, and Evidence from Agricultural Markets in Uganda." *Quarterly Journal of Economics* 132: 1055–1100.
- Coomes, O. T., S. J. McGuire, E. Garine, S. Caillon, D. McKey, E. Demeulenaere, D. Jarvis, G. Aistara, A. Barnaud, P. Clouvel, and L. Emperaire. 2015. "Farmer Seed Networks Make a Limited Contribution to Agriculture? Four Common Misconceptions." *Food Policy* 56: 41-50.
- Cromwell, E., H. Friis, and M. Turner. 1992. *The Seed Sector in Developing Countries: A Framework for Performance Analysis*. Wallingford, UK: CAB International.
- de Boef, W. S., H. Dempewolf, J. M. Byakweli, and J. M. M. Engels. 2010. "Integrating Genetic Resource Conservation and Sustainable Development into Strategies to Increase the Robustness of Seed Systems." *Journal of Sustainable Agriculture* 34(5): 504–531.
- Demo, P., B. Lemaga, R. Kakuhenzire, S. Schulz, D. Borus, I. Barker, G. Woldegiorgis, M. L. Parker, and E. C. Schulte-Geldermann. 2015. "Strategies to Improve Seed Potato Quality and Supply in Sub-Saharan Africa: Experience from Interventions in Five Countries." In *Potato and Sweetpotato in Africa: Transforming the Value Chains for Food and Nutrition Security*, edited by J. Low, M. Nyongesa, S. Quinn, and M. L. Parker, 155–167. Oxfordshire, UK: CAB International.
- Dixon, A. G. O., R. U. Okechukwu, M. O. Akoroda, P. Ilona, F. Ogbe, C. N. Egesi, P. Kulakow, G. Semakula, B. Maziya-Dixon, P. Iluebbey, M. O. Yoweni, C. Geteloma, B. James, O. N. Eke-Okoro, L. Sanni, P. Ntawuruhunga, G. Tarawali, N. Mahungu, J. Lemchi, C. I. Ezedinma, E. Okoro, E. Kaniu, A. A. Adeniji, and K. Nwosu. 2011. *Improved Cassava Variety Handbook*. Ibadan, Nigeria: International Institute for Tropical Agriculture.
- Donkor, E., S. Onakuse, J. Bogue, and I. d. L. R. Carmenado. 2017. "The Impact of the Presidential Cassava Initiative on Cassava Productivity in Nigeria: Implication for Sustainable Food Supply and Food Security." *Cogent Food & Agriculture* 3 (1): 1368857.
- Eaton, D., R. Tripp, and N. Louwaars. 2006. "The Effects of Strengthened Ipr Regimes on the Plant Breeding Sector in Developing Countries." Paper presented at the annual meeting of the International Association of Agricultural Economists, Queensland, Australia, August 12–18.

- FAO (Food and Agriculture Organization of the United Nations). 2010. *Quality Declared Planting Material Protocols and Standards for Vegetatively Propagated Crops*. FAO Plant Production and Protection Paper 195. Rome: Food and Agriculture Organization of the United Nations.
- . 2020. FAOSTAT database. Accessed on July 1, 2020. <http://faostat.fao.org>.
- Floro, I. V., O. Victorino, R. A. Labarta, L. A. B Lopez-Lavalle, J. M. Martinez, and T. M. Ovalle. 2017. “Household Determinants of the Adoption of Improved Cassava Varieties Using Dna Fingerprinting to Identify Varieties in Farmer Fields: A Case Study in Colombia.” *Journal of Agricultural Economics* 69: 518–536.
- FMARD (Federal Ministry of Agricultural and Rural Development, Nigeria). 2014. *Agricultural Transformation Agenda: We Will Grow Nigeria’s Agricultural Sector*. Draft for discussion. Abuja, Nigeria: Federal Ministry of Agricultural and Rural Development.
- Fuglie, K. O., W. Adiyoga, R. Asmunati, S. Mahalaya, and R. Suherman. 2006. “Farm Demand for Quality Potato Seed in Indonesia.” *Agricultural Economics* 35 (3): 257–266.
- Gatto, M., D. P. Le, G. Pacillo, M. Maredia, R. Labarta, G. Hareau, and D. J. Spielman. 2020. *Policy Options for Advancing Seed Systems for Vegetatively Propagated Crops in Vietnam*. RTB Working Paper 2020-1. Lima, Peru: International Potato Center.
- . 2021. “Policy Options for Advancing Seed Systems for Vegetatively Propagated Crops in Vietnam.” *Journal of Crop Improvement*. <https://doi.org/10.1080/15427528.2021.1881011>
- Gibson, R. W., R. O. M. Mwanga, S. Namanda, S. C. Jeremiah, and I. Barker. 2009. *Review of Sweetpotatoes in East and Southern Africa*. Integrated Crop Management Working Paper 2009-1. Lima, Peru: International Potato Center.
- Gildemacher, P. R., P. Demo, I. Barker, W. Kaguongo, G. Woldegiorgis, W. W. Wagoire, M. Wakahiu, C. Leeuwis, and P. C. Struik. 2009. “A Description of Seed Potato Systems in Kenya, Uganda and Ethiopia.” *American Journal of Potato Research* 86 (5): 373–382.
- Gildemacher, P., W. Kleijn, D. Ndung’u, I. Kapran, J. Yogo, R. Laizer, D. Nimpagritse, A. Kadeoua, D. Karnja, C. Simbashizubwoba, A. Ntamavukiro, O. Niangado, P. Oyee, A. N. Chebet, D. Marandu, E. Minneboo, G. Gitu, S. Walsh, and S. Kubgei. 2017. *Effective Seed Quality Assurance*. KIT Working Paper 2017-2. Amsterdam: KIT Royal Tropical Institute.
- Gildemacher, P. R., E. Schulte-Geldermann, D. Borus, P. Demo, P. Kinyae, P. Mundia, and P. C. Struik. 2011. “Seed Potato Quality Improvement through Positive Selection by Smallholder Farmers in Kenya.” *Potato Research* 54: 253–266.
- Harahagazwe, D., B. Condori, C. Barreda, A. Bararyenya, A. A. Byarugaba, D. A. Kude, C. Lung’aho, C. Martinho, D. Mbiri, B. Nasona, B. Ochieng, J. Onditi, J. M. Randrianaivoarivony, C. M. Tankou, A. Worku, E. Schulte-Geldermann, V. Mares, F. de Mendiburu, and R. Quiroz. 2018. “How Big Is the Potato (*Solanum tuberosum* L.) Yield Gap in Sub-Saharan Africa and Why? A Participatory Approach.” *Open Agriculture* 3(2):180–189.
- Hassena, M., O. Hospes, and B. De Jonge. 2016. “Reconstructing Policy Decision-Making in the Ethiopian Seed Sector: Actors and Arenas Influencing Policymaking Process.” *Public Policy and Administration Research* 6 (2): 84–95.
- IFPRI (International Food Policy Research Institute), CIAT (International Center for Tropical Agriculture), IITA (International Institute for Tropical Agriculture), CIP (International Potato Center), and MSU (Michigan State University). 2019. “Making Seed Systems and Markets for Vegetatively Propagated Crops (VPCs) Work for the Poor: A Cross-Country Study of Kenya, Nigeria, and Vietnam.” Harvard Dataverse. Accessed January 12, 2019. <https://doi.org/10.7910/DVN/MSIMRE>.

- ITC (International Trade Center). 2018. “International Trade Statistics 2001–2020.” Accessed February 14, 2021. <https://www.intracen.org/itc/market-info-tools/trade-statistics>.
- Jaffee, S., and J. Srivastava. 1994. “The Roles of the Private and Public Sectors in Enhancing the Performance of Seed Systems.” *World Bank Research Observer* 9 (1): 97–117.
- Kaguongo, W., G. Maingi, I. Barker, N. Nganga, and J. Guenther. 2014. “The Value of Seed Potatoes from Four Systems in Kenya.” *American Journal of Potato Research* 91(1): 109–118.
- Kapinga, R. 2013. “Summary of Strategy for Sustainable Seed Systems of Vegetatively Propagated Crops (VPCs) in Sub-Saharan Africa.” Unpublished.
- Kenya, EOP (Executive Office of the President). 2017. “The Big Four.” Accessed January 2020. <https://big4.delivery.go.ke/>.
- Kenya, MoALF (Ministry of Agriculture, Livestock and Fisheries). 2016. *The National Potato Strategy 2016-2020*. Nairobi.
- Kenya, MoALFI (Ministry of Agriculture, Livestock, Fisheries and Irrigation). 2018. *Agricultural Sector Transformation and Growth Strategy: Towards Sustainable Agricultural Transformation and Food Security in Kenya. 2019–2029*. Nairobi.
- Kloppenborg, J. 1988. *First the Seed. The Political Economy of Plant Biotechnology, 1492–2000*. Cambridge, UK: Cambridge University Press.
- . 2010. “Impeding Dispossession, Enabling Repossession: Biological Open Source and the Recovery of Seed Sovereignty.” *Journal of Agrarian Change* 10 (3): 367–388.
- Koo, B., C. Nottenburg, and P. G. Pardey. 2004. “Plants and Intellectual Property: An International Appraisal.” *Science* 306 (5,700): 1295–1297.
- Kosmowski, F., A. Aragaw, A. Kilian, A. Ambel, J. Ilukor, B. Yigezu, and J. Stevenson. 2019. “Varietal Identification in Household Surveys: Results from Three Household-Based Methods against the Benchmark of DNA Fingerprinting in Southern Ethiopia.” *Experimental Agriculture* 55 (3): 371–385.
- Laibuni, N. M. and J. M. Omiti. 2014. *Market Structure and Price: An Empirical Analysis of Irish Potato Markets in Kenya*. Nairobi: Future Agricultures Consortium.
- Le D. P., R. A. Labarta, S. de Haan, M. Maredia, L. A. Becerra, L. Nhu, T. Ovalle, V. Nguyen, N. Pham, H. Nguyen, H. Nguyen, K. Le, and H. H. Le. 2019. *Characterization of Cassava Production Systems in Vietnam*. CIAT Working Paper 480. Hanoi: International Center for Tropical Agriculture.
- Lesser, W. 2000. “An Economic Approach to Identifying an ‘Effective Sui Generis System’ for Plant Variety Protection under TRIPS.” In *Agriculture and Intellectual Property Rights*, edited by V. Santaniello, R. Evenson, D. Zilberman, and G. Carlson, 53–76. Wallingford, UK: CAB International.
- Louwaars, N. P., W. S. de Boef, and J. Edeme. 2013. “Integrated Seed Sector Development in Africa: A Basis for Seed Policy and Law.” *Journal of Crop Improvement* 27: 186–214.
- Lua, H. T., J. M. Roshetko, D. Catacutan, and L. D. Thinh. 2015. “A Review of Policy Constraints and Opportunities for the Sustainable Delivery of Quality Fruit Tree Germplasm in Vietnam.” *International Journal of Agriculture Innovations and Research* 4(3): 536–543.
- Maredia M. K., B. Reyes, J. Manu-Aduening, A. A. DAnkyi, K. M. Hamazakaza, I. Rabbi, P. Kulakow, E. Parkes, T. Abdoulaye, E. Katungi, and B. Raatz. 2016. *Testing Alternative Methods of Varietal Identification Using DNA Fingerprinting: Results of Pilot Studies in Ghana and Zambia*. MSU

- International Development Working Paper 149. East Lansing: Department of Agricultural, Food, and Resource Economics, Michigan State University.
- McEwan, M., C. Almekinders, P. E. Abidin, M. Andrade, T. Carey, R. Gibson, A. Naico, S. Namanda, and S. Schulz. 2015. "Can Small Still Be Beautiful? Moving Local Sweetpotato Seed Systems to Scale in Sub-Saharan Africa." In *Potato and Sweetpotato in Africa: Transforming the Value Chains for Food Security and Nutrition*, edited by J. Low, M. Nyongesa, S. Quinn, and M. L. Parker, 289–310. Oxfordshire, UK: CAB International.
- McEwan, M. A., D. J. Spielman, J. J. Okello, G. Hareau, B. Bartle, D. G. Mbiru, E. O. Atieno, B. A. Omondi, T. Wossen, L. C. Gonzalez, T. Abdoulaye, and M. Maredia. 2021. *Exploring the Regulatory Space for Improving Availability, Access and Quality of Vegetatively Propagated Crop Seed: The Case of Seed Potato in Kenya*. RTB Working Paper no. 2021-1. Lima, Peru: International Potato Center.
- McGuire, S. and L. Sperling. 2016. "Seed Systems Smallholder Farmers Use." *Food Security* 8 (1): 179–195.
- Morris, M. L., ed. 1998. *Maize Seed Industries in Developing Countries*. Boulder, CO: Lynne Rienner.
- Munyi, P., and B. De Jonge. 2015. "Seed Systems Support in Kenya: Consideration for an Integrated Seed Sector Development Approach." *Journal of Sustainable Development* 8 (2): 161–173.
- Muthoni, J. and D. O. Nyamongo. 2009. "A Review of Constraints to Ware Irish Potatoes Production in Kenya." *Journal of Horticulture and Forestry* 1 (7): 98–102.
- Muthoni, J. J., H. Shimelis, and R. Melis. 2013. "Potato Production in Kenya: Farming Systems and Production Constraints." *Journal of Agricultural Science* 5 (5): 182–197.
- Naseem, A., D. J. Spielman, and S. W. Omamo. 2010. "Private-sector Investment in R&D: A Review of Policy Options to Promote Its Growth in Developing-Country Agriculture." *Agribusiness* 26 (1): 143–73.
- Nweke, F. I. 2010. "Controlling Cassava Mosaic Virus and Cassava Mealybug in Sub-Saharan Africa." In *Proven Successes in Agricultural Development: A Technical Compendium to Millions Fed*, edited by D. J. Spielman and R. Pandya-Lorch, 99–122. Washington, DC: International Food Policy Research Institute.
- Nweke, F. I., D. S. C. Spencer, and J. K. Lynam. 2002. *The Cassava Transformation: Africa's Best Kept Secret*. East Lansing, MI: Michigan State University Press.
- Okello, J. J., Y. Zhou, N. Kwikiriza, S. Ogutu, I. Barker, E. Schulte-Geldermann, E. Atieno, and J. T. Ahmed. 2017. "Productivity and Food Security Effects of Using of Certified Seed Potato: The Case of Kenya's Potato Farmers." *Agriculture & Food Security* 6 (1): 1–9.
- Pal, S. and R. Tripp. 2002. "India's seed Industry Reforms: Prospects and Issues." *Indian Journal of Agricultural Economics* 57 (3): 443–458.
- Pal, S., R. Tripp, and N. P. Louwaars. 2007. "Intellectual Property Rights in Plant Breeding and Biotechnology: Assessing Impact on the Indian Seed Industry." *Economic and Political Weekly*: 231–40.
- Parker, M. 2019. *Production of Apical Cuttings of Potato*. Lima, Peru: International Potato Center.
- Parker M. L., J. W. Low, M. Andrade, E. Schulte-Geldermann, and J. Andrade-Piedra. 2019. "Climate Change and Seed Systems of Roots, Tubers and Bananas: The Cases of Potato in Kenya and Sweetpotato in Mozambique." In *The Climate-Smart Agriculture Papers: Investigating the Business of a Productive, Resilient and Low Emission Future*, edited by T. S. Rosenstock, A. Nowak, and E. Girvetz, 99–112. Cham, Switzerland: SpringerOpen.

- Rabbi, I. Y., P. A. Kulakow, J. A. Manu-Aduening, A. A. Dankyi, J. Y. Asibuo, E. Y. Parkes, T. Abdoulaye, G. Girma, M. A. Gedil, P. Ramu, and B. Reyes. 2015. "Tracking Crop Varieties Using Genotyping-By-sequencing Markers: A Case Study Using Cassava (*Manihot esculenta* Crantz)." *BMC Genetics* 16. <https://doi.org/10.1186/s12863-015-0273-1>
- Rana, M. A. 2010. "Formalising the Informal: The Commercialisation of Bt Cotton in Pakistan." PhD dissertation, Melbourne School of Land and Environment, University of Melbourne, Australia.
- Reardon, T., and C. P. Timmer. 2012. The Economics of the Food System Revolution. *Annual Review of Resource Economics* 4 (1): 225–264.
- RTB (CGIAR Research Program on Roots, Tubers, and Bananas). 2016. *Multi-Stakeholder Framework for Intervening in RTB Seed Systems*. RTB Working Paper 2016-1. Lima: International Potato Center.
- Schulte-Geldermann, E., G. Wachira, B. Ochieng, and I. Barker. 2013. "Effect of Field Multiplication Generation on Seed Potato Quality in Kenya." Unpublished. Accessed May 15, 2020. <https://core.ac.uk/download/pdf/132667407.pdf>
- Scoones, I., and J. Thompson. 2011. "The Politics of Seed in Africa's Green Revolution: Alternative Narratives and Competing Pathways." *IDS Bulletin* 42 (4): 1–23.
- Spielman, D. J. 2020. "Seed Policies and Regulatory Reforms." In *Sustaining Africa's Agrifood System Transformation: The Role of Public Policies*, edited by D. Resnick, X. Diao, and G. Tadesse, 26–32. ReSAKSS 2020 Annual Trends and Outlook Report. Washington, DC, and Kigali, Rwanda: International Food Policy Research Institute and AKADEMIYA2063.
- Spielman, D. J., and A. Kennedy. 2016. "Towards Better Metrics and Policymaking for Seed System Development: Insights from Asia's Seed Industry." *Agricultural Systems* 147: 111–122.
- Spielman, D. J., and X. Ma. 2016. "Private Sector Incentives and the Diffusion of Agricultural Technology: Evidence from Developing Countries." *Journal of Development Studies* 52 (5): 696–717.
- Spielman, D. J., and M. Smale. 2017. *Policy Options to Accelerate Variety Change among Smallholder Farmers in South Asia and Africa South of the Sahara*. IFPRI Discussion Paper 01666. Washington, DC: International Food Policy Research Institute.
- Tesfaye, A., B. Lemaga, J. A. Mwakasendo, Z. Nzohabonayoz, J. Mutwares, K. Y. Wanda, P. M. Kinyae, O. Ortiz, C. Crissman, and G. Thiele. 2010. *Markets for Fresh and Frozen Potato Chips in the ASARECA Region and the Potential for Regional Trade: Ethiopia, Tanzania, Rwanda, Kenya, Burundi and Uganda*. Social Sciences Working Paper 2010-1. Lima: International Potato Center.
- Thiele, G., D. Dufour, P. Vernier, R. O. Mwanga, M. L. Parker, E. Schulte Geldermann, B. Teeken, T. Wossen, E. Gotor, E. Kikulwe, and H. Tufan. 2021. „A Review of Varietal Change in Roots, Tubers and Bananas: Consumer Preferences and Other Drivers of Adoption and Implications for Breeding.“ *International Journal of Food Science & Technology* 56 (3): 1076–1092.
- Thiele, G., A. Khan, B. Heider, J. Kroschel, D. Harahagazwe, M. Andrade, M. Bonierbale, M. Friedmann, D. Gemenet, M. Cherinet, R. Quiroz, E. Faye, and O. Dangles. 2017. „Roots, Tubers and Bananas: Planning and Research for Climate Resilience.“ *Open Agriculture* 2 (1): 350–361.
- Thomas-Sharma, S., J. Andrade-Piedra, M. Carvajal Yepes, J. F. Hernandez Nopsa, M. J. Jeger, R. A. C. Jones, P. Kromann, J. P. Legg, J. Yuen, G. A. Forbes, and K. A. Garrett. 2017. "A Risk Assessment Framework for Seed Degeneration: Informing an Integrated Seed Health Strategy for Vegetatively Propagated Crops." *Phytopathology* 107 (10): 1123–1135.

- Tin, H. Q., N. H. Cuc, T. T. Be, N. Ignacio, and T. Berg. 2011. "Impacts of Seed Clubs in Ensuring Local Seed Systems in the Mekong Delta, Vietnam." *Journal of Sustainable Agriculture* 35 (8): 840–854.
- Tripp, R., and N. Louwaars. 1997. "Seed Regulation: Choices on the Road to Reform." *Food Policy* 22 (5): 433–446.
- Tripp, R., and D. Rohrbach. 2001. "Policies for African Seed Enterprise Development." *Food Policy* 26 (2): 147–161.
- Wossen, T., T. Abdoulaye, A. Alene, M. G. Haile, S. Feleke, A. Olanrewaju, and V. Manyong. 2017. "Impacts of Extension Access and Cooperative Membership on Technology Adoption and Household Welfare." *Journal of Rural Studies* 54: 223–233.
- Wossen, T., T. Abdoulaye, A. Alene, P. Nguimkeu, S. Feleke, I. Y. Rabbi, M. G. Haile, and V. Manyong. 2019. "Estimating the Productivity Impacts of Technology Adoption in the Presence of Misclassification." *American Journal of Agricultural Economics* 101 (1): 1–6.
- Wossen, T., D. J. Spielman, T. Abdoulaye, and P. L. Kumar. 2020. *The Cassava Seed System in Nigeria: Opportunities and Challenges for Policy and Regulatory Reform*. RTB Working Paper 2020-2. Lima, Peru: International Potato Center.

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