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Market-led options to scale up legume seeds in developing countries: Experiences from the Tropical Legumes Project

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Abstract

There are several hurdles to ensure sustainable seed production and consistent flow of improved legume varieties in sub-Saharan Africa (SSA) and South Asia (SA). The unreliable demand, autogamous nature of most of the grain legumes, and slow variety replacement rate by smallholder farmers do not provide strong incentive for private seed companies to invest in legume seed business. Unless a well thought-out and comprehensive approach to legume seed delivery is developed, current seed shortages will continue, eroding emerging market opportunities. The experiences reported here are collated through a 10-year partnership project, the Tropical Legumes in SSA and SA. It fostered innovative public–private partnerships in joint testing of innovative market-led seed systems, skills and knowledge enhancement, de-risking private sector initiatives that introduced in new approaches and previously overlooked entities in technology delivery. As new public and private seed companies, individual seed entrepreneurs and farmer organizations emerged, the existing ones enhanced their capacities. This resulted in significant rise in production, availability and accessibility of various seed grades of newly improved and farmer demanded legume varieties in the target countries.

KEYWORDS
decentralized seed production and supply, improved legume variety innovative legume seed systems, multi-stakeholder platform, sub-Saharan Africa and South Asia, variety promotion

1 | INTRODUCTION

Various technical and institutional challenges have affected recent research and development efforts to boost tropical legumes production and productivity in sub-Saharan Africa (SSA) and South Asia (SA). In SSA, the majority of legume farmers are women that rely on non-mechanized family labour for farm operations on their small landholdings (Monyo & Varshney, 2016; Nhamo, Mupangwa, Siziba, Gatsi, & Chakazunga, 2003). They use rudimentary technologies including unimproved or old improved varieties that are often susceptible to multiple production and postharvest constraints (Walker & Alwang, 2015). The shortage of quality seed of improved varieties is a major contributing cause of persistent low yields observed among smallholder farmers in SSA (Monyo & Laxmipathi, 2014; Monyo & Varshney, 2016) and in SA including India where 18.67 million tons (t) of grain legumes (pulses) were produced on about 25.24 million hectares (ha) during the period 2012–2017. To cover 30% of the total pulse area in India alone using quality seed, 30–350,000 t of quality seed must be produced annually.

Hybrid seed of maize and vegetables have fairly well-structured production and marketing systems with private sector participation in SSA and SA. The successful maize seed system, has effectively given smallholder farmers in Africa access to new genetics (Byerlee & Eicher, 1997; Smale & Jayne, 2003). Meanwhile, formal seed systems of legume crops remain inadequately developed despite efforts to emulate success in cereal seed systems. Traditionally, dissemination of legume seed and varieties has been done through the informal seed system particularly farmer groups with limited geographical coverage (Rubyogo, Sperling, Buruchara, & Muthoni, 2010). Consequently, the informal seed systems approach extended the period between release and the wider use of these varieties by smallholder farmers. Furthermore, the informal sector focuses on genetic diversity, which makes the legume seed demand highly fragmented due to agroecological and farmers'/consumers' demand (Rubyogo, Magreta, et al., 2016a). On the one hand, in instances where seed is relatively available, the supply composition is still predominantly old varieties (Blaustein, 2008; Mhango, Snapp, & Phiri, 2013). On the other hand, due to the large institutional market in SSA, legume seed is often provided in large packs (50–100 kg) that are unaffordable for smallholder farmers—a practice that further strengthens the perception that farmers do not purchase legume seed even when it is made available.

The objective of this article is to provide lessons on scaling legume seed systems through (a) adopting market-oriented legume seed systems; (b) increasing genetic diversity of legumes to respond to the various needs of smallholder legume farmers; (c) strengthening diversified production of early generation seed; (d) professionalizing decentralized production of certified seed; and (e) catalyzing private companies investment by establishing/strengthening partnerships for increased seed production and marketing.

The experience reported in this paper emerged from seed systems action research for development initiatives. The research efforts were carried out in the framework of the Tropical Legumes (TL) projects supported by the Bill & Melinda Gates Foundation (BMGF)

and implemented over 10 years (between 2007 and 2017); covering 11 countries (India, Bangladesh, Ethiopia, Uganda, Tanzania, Kenya, Mozambique, Nigeria, Niger, Malawi and Mali) and six legume crops: chickpea *(Cicer arietinum)*, groundnut *(Arachis hypogaea)*, cowpea *(Vigna unguiculata)*, soybean *(Glycine max)*, pigeonpea *(Cajanus cajan)* and common bean *(Phaseolus vulgaris)*. However, since 2015, the projects focused on four legumes (common beans, chickpea, cowpea and groundnut) in eight countries. In the paper, we focus on five countries (Ethiopia, Mali, Nigeria, Tanzania and India) and four crops (common bean, cowpea, chickpea and groundnut) using data from the period 2007–2017 to show how to bring wider systemic change in legume seed production and supply in the context for smallholder farmers in SSA and SA.

2 | THEORETICAL PERSPECTIVE AND INTERVENTION APPROACH

Improving farm-level production and productivity requires improved access and use of quality seed of improved varieties by smallholder farmers who are mostly legume farmers (Akpo et al., 2014). In the past decades, many varieties have been developed in SSA and SA including 195 high-yielding varieties of grain legumes (pulses) released during the last 10 years by Indian NARS. However, very few have made their way to the farmers' fields. Usually, the access to these varieties has been limited by reliance on formal or informal seed systems and an integrated and pluralistic approach to cater for various farmers' needs and conditions (Rubyogo et al., 2010). A sustainable seed system should embody key social institutional dynamics that enable effective delivery to the end users (Akpo et al., 2014). The research design for this paper draws on collaborative and market-led approaches that embrace legume variety dissemination and use by smallholder farmers in SSA and SA. It has been proven that the partnership between farmers, national agricultural research programs, the private seed producers and grain traders enhanced the sustainability and the adoption of new improved chickpea and beans varieties in Ethiopia (Ojiewo et al., 2015; Tebeka, Katungi, Rubyogo, Sserunkuuma, & Kidane, 2017). Collaborative research has been framed as an approach that engages most stakeholders in the research processes from problem definition to intervention design and implementation, to joint assessment and decision to implement at scale (Buruchara et al., 2011). It convenes international and national research institutes, universities, development and humanitarian organizations, policy makers and community actors to solve complex problems faced by the community. Collaborative research calls for partnership building between relevant stakeholders to solve the legume value chain problems. Forming a multi-stakeholders' platform is one way to get such a partnership shaped and operational.

For collaborative research to effectively address legume seed value chain issues in a sustainable way, a market-oriented lens is essential. A market-led approach to legume dissemination starts from identifying farmers' variety preferences among several released varieties. The identified ones will be the focus of seed multiplication and supply. The market-led approach to legume seed dissemination relied on the "8Ps of marketing", that is, product design, process, people, pricing, place, physical evidence, promotion and positioning. For seed technology to work at wider scale, there is need to embrace mechanisms that expose the largest possible numbers of target groups. In the experience reported in this paper, the intervention approaches embraced mechanisms that allowed the quality seed of improved varieties to reach the various target groups at scale by working with multiple seed value chain actors using proven pluralistic bean seed systems practices (Buruchara et al., 2011; Rubyogo, Myers, et al., 2016b; Rubyogo et al., 2010). The end-users were able to assess the legume varieties and make their own decisions about which one (s) to adopt.

As part of the process, the practices that promote improved legume variety production and use were prioritized. Generally, the formal seed systems alone did not facilitate access by smallholder farmers to diverse legume varieties; farmers usually sourced about 90% of their seed from the informal sector (McGuire & Sperling, 2016). The 10% of seed which they sourced from the formal sector was predominantly old ("ruling") varieties which might already have been in the hands of farmers through the local seed exchanges (Rubyogo, Sperling, & Asefa, 2007). Therefore, the seed system efforts were not translated into variety replacement. To overcome the situation, the Quality Declared Seed (QDS) approach was scaled up in most countries but at the same time catalyzing private companies' investments to facilitate complementarities between the two seed systems approaches. In this paper, QDS systems facilitated the production and supply of quality seed produced from either basic seed or certified seed at the community level with limited certification activities (one to two visits of seed certification officer), marketed at the community level to reach a larger number of smallholder farmers than the traditional certified seed channel (FAO, 2006). This is a seed production model already legalized in many SSA countries including Ethiopia, Tanzania and Uganda. The Truthfully Labeled Seed (TLS) model of quality seed production used in India is like QDS, and much of the production of certified seed is done by seed companies. For instance, in India, to produce quality seeds of pulses, several seed villages were established involving groups of farmers organized in farmer seed producers' societies in different agroecological regions. Furthermore, considering the importance of quality seed, the Department of Agriculture, Cooperation and Farmers Welfare (DAC&FW), the Ministry of Agriculture and Farmers Welfare, the Government of India approved an ICAR project "Creation of seed hubs for increasing indigenous production of pulses in India" to establish 150 seed hubs in 24 states (with a total outlay of approx. US$ 3,360 million).This project was implemented through Indian Council of Agricultural Research-Indian Institute of Pulses Research (ICAR-IIPR), Kanpur, India. Nine Indian Agricultural Research Institutes (ICAR Institutes), 44 All India Coordinated Research Project Centres (AICRP Centers) located in different State/Central Agricultural Universities; and 97 Krishi Vigyan Kendras (KVKs i.e. Agriculture Science Centres)

are partners in this project. The ICAR-Agricultural Technology Application Research Institutes (ICAR-ATARIs) were collaborators for implementation of the Seed Hubs project. The project had a provision of a one-time grant of US$ 75,000 in the first year per seed hub to support seed infrastructure (i.e. a seed processing plant and storage facility). In addition, there was provision of US$ 150,000 for each seed hub as a revolving fund to meet various expenses for production, procurement and processing of seeds during the period of 2016–2018. The profit generated from the seed sales was used by the seed hubs to develop other facilities to increase quality seed production of targeted pulses.

Within three years, all 150 seed hubs will become self-reliant and each centre will continue to produce 100 t of quality (certified) seed of different pulses in a sustainable manner. Total 150 seed hubs will be producing a total 15,000 t of quality seed of newly released high-yielding varieties (i.e. not older than 10 years) of different pulses on a sustainable basis which is likely to ensure productivity and production increase of various pulses in India (Chaturvedi, Katiyar, Lamicheney, & Singh, 2016).

For both QDS and TLS, community-selected farmers were registered as seed producers. QDS and TLS models helped to reach farmers in remote areas with high-quality seed that would otherwise be difficult due to the bulky nature of legume seeds and associated cost of transportation and storage. In this paper, we use the phrase early generation seeds to refer to prebasic and basic seeds.

Overall the approach was hinged on several overarching components including partnership building, skills and knowledge enhancement through trainings, exposure to innovative seed systems approaches as well as intensifying efforts to reach the last-mile smallholder farmers with improved technologies.

2.1 | Partnership building

Across countries and legume crops, we adopted an inclusive pluralistic and integrated seed systems approach that recognizes the complementary roles of seed producers such as individuals, seed companies, Government Organizations (GOs) and Farmer Organizations (FOs) While initially, variety development and production of early generation seed were vested exclusively in the National Agricultural Research Systems (NARS), inherent inefficiencies inadvertently caused delays in the scale and scope of adoption of new varieties. Under the project approach, due recognition was given to private seed producers to complement the NARS. To initiate a demand-led legume system, multi-stakeholders platforms were established and their roles were to (a) determine variety demand and its/their quantities (b), develop a seed roadmap to respond to commodity demand, (c) share roles and responsibility along the legume seed value chains, (d) identify and source complementary support services (e), catalyze additional seed systems investments from private and public sector (f) and review annual progress and make necessary adjustments. The seed producers were supported by a range of public–private partners, such as Non-Government Organizations (NGOs), FOs and public extension teams, providing context-based complementary services such as transfer of knowledge and skills, capacity development for seed quality control and linkages to mechanization and financial services (see Figure 1).

Partners developed joint work plans for project research and implementation, and agreed on roles and responsibilities through formal memoranda of understanding (Rubyogo et al., 2010). The seed dissemination approaches used were: farmers' variety preference identification, wider variety testing, organization of seed producer-led demonstrations and organizing field days, stakeholders' capacity building in technical and business skills, information provision on new varieties, linkage strengthening among different actors and use of mass communication (i.e. radio, TV and printed media) and its impacts on farmers' practices and knowledge about promoted seed technologies. Although these multi-stakeholder platforms were initially facilitated by the Consultative Group on International Agricultural Research (CGIAR) centers and NARS researchers, as the project progressed there was increased ownership by the national actors. The private sector actors and farmers' organizations showed interest in the approach and are now increasingly taking full responsibility. For instance, the Association of Pulse exporters in Ethiopia agreed to

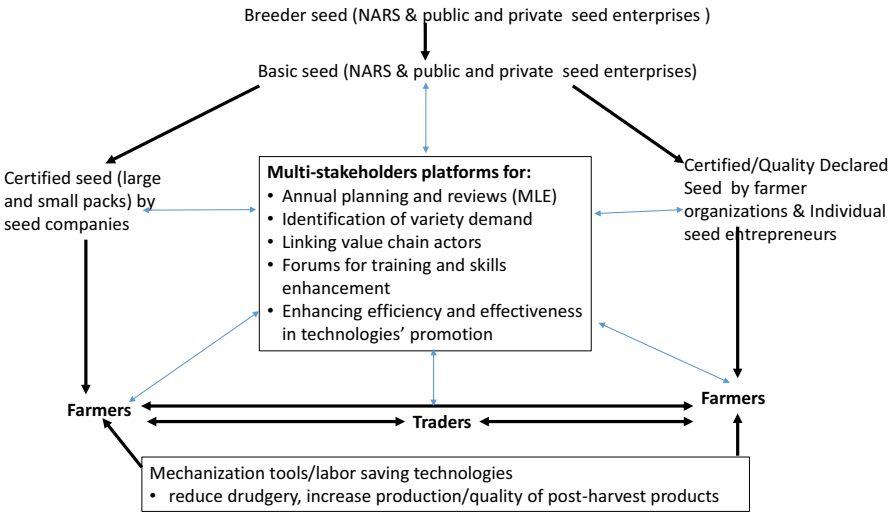

FIGURE 1 Integrated seed systems and use of multi-stakeholders' platforms for enhancing seed production and inclusive access

provide financial support to the pulse stakeholders' annual review and planning meeting.

Seed systems activities under the project were thus implemented as part of country-led and nationally owned legume research for development plans, strategies and priorities. Several actors incorporated the legume seed activities in their yearly programming. The engagement of commodity traders/off-takers (e.g. Raphael Group in Tanzania and ACOS in Ethiopia), private seed companies, individual seed entrepreneurs, NGOs, grain traders, community-based organizations (CBOs) and FOs greatly enhanced the prospects for demand-led seed systems which is key to the sustainability of intended outcomes. The NARS supported and empowered the partners in two main ways. First, the framework ensured accountability to one another, and the NARS ensured the availability and accessibility of early generation seed to feed into certified seed and QDS production plans of private producers and later, grain production. Second, technical support to private seed companies was provided through training in seed business management, access to parental seed, derisking of private sector investments by supporting demand creation activities for new varieties (i.e. demonstration/field days at a wider scale), advisory services on the appropriateness and suitability of the varieties, testing innovative seed production and marketing such as variety non-exclusive licensing, and marketing of farmer friendly seed packs.

2.2 | Roles and responsibilities

The multi-stakeholders' platforms, the different stakeholders involved in the process are mutually accountable for the strengthening of the seed systems in the respective geographies. The first stage was to agree on roles based on the competencies and complementarities (Table 1). Whether technical (NARS), policy-related (Ministry of Agriculture), business development (seed companies and enterprises), farm operations (farmers), the different stakeholders contributed to get the collective action.

2.3 | Capacities enhancement

To expand and sustain the seed systems initiatives under TL project, partners along the seed and grain value chains of various legumes were engaged in skills and knowledge enhancement of strategic partners. A two-tier training model was adopted. The first tier involved centralized training of trainers, conducted for members of the respective multi-stakeholder platforms. During this training, the CGIAR and NARS crop scientists, seed systems and agrobusiness specialists enhanced the capacities of identified trainers from NARS, representatives of seed producers and related service providers. The training of trainers focused on various seed value chain components and soft skills including partnership development and strengthening, variety identification and seed quality maintenance, variety demand identification and creation, scaling up through market options and research and development linkages. The second tier comprised decentralized training sessions conducted at the local levels mainly for individual legumes seed and grain producers and marketers.

2.4 | Exposure to innovative technologies and approaches

One of the key pillars of the pluralistic legume seed systems was to develop and create demand for new technologies and approaches among the target communities. Several innovative strategies were tested or adapted to enhance exposure. For instance, on-farm demonstrations, cluster demonstrations and farmers participatory variety selection (FPVS) trials, seed fairs and field days were hosted by seed value chain actors particularly village seed traders (commonly known as agro-dealers in East Africa) supported by major seed suppliers rather than the NARS (role traditionally carried out by NARS), use of information communication technologies (ICT) tools (WhatsApp groups) and marketing of small packs by the private and public seed companies. In India, a mobile-based App "Chana Mitra" (i.e. Chickpea Friend) was developed to share package of practices for raising good chickpea crop. Pamphlets and extension bulletins containing technology packages were also published and distributed among farmers for growing seed crop. All these innovative demand creation tools exposed farmers to new varieties and complementary technologies, while gaining affordable access to these technologies within their proximity and with diverse and wider pool to select from.

2.5 | Geographic and socio-economic coverage

The aim of technology development and transfer is to ensure that the technologies reach the last-mile end users. A critical step was to map out the areas targeted for wider impact, while taking care of socio-economic categories of target communities within the mapped regions. The partnerships approach proved a key pillar enhancing efficiency and effectiveness in technology transfer. Engaging pluralistic seed actors, particularly in seed production and marketing was a way to reduce the gap between formal and informal sources, increase diversity of varieties and seed sources and enhance seed access especially by smallholder farmers.

2.6 | Methods of data collection, synthesis, analysis and reviews

Data were gathered on: the categories of seed actors involved, production of different seed classes, demand creation activities, that is, demonstrations plots, field days, radio and TV events, newspapers, flyers, fairs and agricultural shows per country. To show the diversity of stakeholders involved in the research process from various level, we compiled and added information gathered on different categories of actors during project implementation. Yearly seed production data over project duration were computed for each country and crop. We calculated the percentage of seed production per project period to show progress made to increase production over time. Improved legume seed production data were plotted to show the trend of seed production increase over years.

TABLE 1 Roles and responsibilities of different partner organizations in collaborative legume seed systems approach adopted under the TL project

Partners	Roles and responsibilities
National Agricultural Research Systems (NARS)	• Development of marketable and preferred legume varieties based on national regional demands • Production and supply of early generation seeds • Provision of information on new varieties • Support other partners' skills and knowledge enhancement • Catalyze the development of legume sub sector at national and regional levels
Ministries of Agriculture (policy making organ)	• Serve as champion of legume value chain development to other government policy makers • Policy support towards legume research and development • Engage and support private sector investors in the legume value chains
Public Seed Enterprises	• Production and marketing/supply of basic and certified seeds • Business opportunities and capacity building for contracted seed growers
Decentralized seed producers	• Test new varieties with support from extension service providers • Production and marketing of seeds in local markets and to local organizations • Local community contacts and wider dissemination of information and seeds
Local seed traders	• Supply of quality seeds of locally acceptable legumes varieties • Wider marketing of improved varieties at low cost through regional and local channels
Local Grain Traders	• Purchase of legume grains (for domestic and export markets) to drive seed production and market • Establishment of basic market infrastructure (storage facilities) • Establishment of grain quality standards
District authorities and Extension Agents	• Support decentralized testing of varieties and provide feedback to researchers • Support decentralized seed production and diffusion • Capacity building in bean seed and grain production, quality control • Enhancement of skills in agribusiness management • Mobilize farmers to produce legumes and link them to local and export markets • Facilitate linkages with service providers in the value chain for example, transporters, cooperatives and researchers • Facilitate acquisition of basic seeds and other technologies
Farmers' groups and Cooperative Unions	• Mobilization of farmers (members) • Provision of agri-inputs (fertilizers, seed) to famers on loan or cash • Purchase of legume grains from the members and other farmers • Establishment of market infrastructure storage, cleaning equipment
Legume exporters	• Testing marketability/suitability of existing and new varieties • Establishment of quality standards and market infrastructure • Purchase and export of quality legumes grain (market guarantee) • Training of collectors/traders on grain quality control systems • Members of legume multi-stakeholders platform
International Research Institutes (CIAT, ICRISAT/ /IITA)	• Provision of legume germplasm • Training in seed production and business skills • Support in the design of innovative legume seed systems approaches for wider impact • Support the development of efficient and productive seed multiplication techniques

Note: Adapted from Rubyogo et al. (2010).

3 | RESULTS

3.1 | Engagement of partners in seed production and marketing

Deliberate efforts were channelled in engaging partners from diverse disciplines at all stages of project planning and in building capacities of the partners, while keeping in mind their varied interests. Overall, between 2007 and 2017, hundreds of partners including public seed enterprises, seed companies, individual seed entrepreneurs, FOs, were involved in seed production and marketing across target countries and supported by NGOs and CBOs (see Table 2). In most countries, the number of private seed companies that invested in legume seed production and dissemination significantly increased from less than 10 to close to 37 in four countries, while the number of small-scale seed entrepreneurs increased from a dozen to hundreds in many countries. More importantly, community seed producers and FOs increased dramatically, from 10 to 470 in Tanzania. The various categories of actors currently involved in seed production and dissemination to smallholder farmers have boosted the seed business both at the community and country levels. The public sector which used to be more dominant in legume seed supply in most countries is now being overtaken by the private sector especially for highly marketable or popular varieties. For instance, in Tanzania where beans are increasingly becoming a food-cash crop, NARS and CIAT

initiated bean multi-stakeholders' platforms coupled with the increased production and marketing of farmer and market preferred varieties. As a result, the number of seed companies engaged in bean seed rose from zero in 2010 to seven companies and one public seed enterprise (Agricultural Seed Agency) producing and marketing about 1,000 t of certified bean seed in 2017. These companies and ASA are in the process of initiating the production of certified groundnut seed. In Ethiopia and Uganda, the supply of quality bean seed (certified and QDS) rose from less than 5% of the national bean seed requirement in 2008 to 15% and 10% in 2016 respectively. In Nigeria, cowpea varieties IT99K-573-1-1 (SAMPEA 14) and IT99K-573-2-1 (SAMPEA 15) which were on the shelf, were produced and promoted widely among farmers and replaced the older ones such as IT90K-208-5 (SAMPEA 9) and IT97K-499-35 (SAMPEA 10). The TL legume project has also provided opportunities for other donors to co-invest in legume seed systems. For instance, USAID—Feed the Future invested in both groundnut and cowpea scaling up projects in Ghana, Mali and Nigeria. In Tanzania, through the Scaling Seed and Technologies Partnership (SSTP) project, USAID-AGRA supported the commercialization of certified bean seed by companies and ASA and facilitated the creation of multi-stakeholders' platform in northern Tanzania (Rubyogo, 2017).

3.2 | Sustainable production and delivery of certified and quality declared legume seed

Three seed classes (basic seed, certified and quality declared/truthfully labelled seed) were produced across legumes and disseminated either for further seed production or to farmers for grain production. The integrated system adopted allowed various actors to engage in the production of different seed classes. In most target countries, the NARS produced and provided breeder and prebasic seed to the private sector for production of basic and certified seeds under close supervision by the national seed regulatory agencies. The private sector then distributed the basic/certified seed to local seed producers (i.e. individual or groups—supported by development partners such as UN agencies, GOs, NGOs, CBOs etc.) for production of quality declared seed or truthfully labelled seed with limited supervision. The distribution of seed production by classes, across countries and legume crops is as shown in Table 3.

TABLE 2 Diverse categories and number of partners engaged in TL project, per country during 2007–2017

	Type and number of partners						
Country	Public seed enterprises	Seed companies	Individual seed entrepreneur	Farmer organization	NGOs	CBOs	Total
Ethiopia	20	4	55	54	–	31	139
Tanzania	6	9	68	456	2	17	541
Mali	2	8	51	40	–	–	101
Nigeria	10	16	598	81	1	–	706
India	2	–	18	6	1	–	27

TABLE 3 Trend of different seed classes production as over project phases

	Class and quantity (tons) of seed produced					
	2007–2010		2011–2014		2015–2017	
Country	BS	CS-QDS	BS	CS-QDS	BS	CS-QDS
Nigeria, cowpea	108.6	1,591.6	165.2	909.9	177.6	1,597.0
Mali, cowpea	22.9	122.0	14.6	278.9	33.7	694.0
Mali, groundnut	48.8	176.0	122.7	1,236	70.97	1,456.8
Nigeria, groundnut	14.8	149.8	36.7	2,119.3	22.7	1,234.6
India, chickpea	3,993.0	48,698	53,179	162,712	14.0	–
India, groundnut	1,037.6	4,580.9	7,050.3	11,891.8	–	–
Ethiopia chickpea	300.5	4,500.8	415.0	8,254.9	676.5	7,925.0
Ethiopia, common bean	758.0	10,071.2	965.8	15,508.1	344.0	8,904.0
Tanzania groundnut	823	10,230.0	1,240.0	15,345.0	240.0	3,592.0

Note: Since 2015, the groundnut in India is no longer part of TLIII and chickpea—India is also limited to Uttar Pradesh (UP).
Abbreviations: BS: Basic seed; CS/QDS: Certified seed/Quality declared seed.

As a result of strong partnerships supported by appropriate capacity building and availability of improved and user-preferred varieties, seed production and supply significantly increased. Between 2007 and 2017, hundreds of thousands tons of assorted seed classes of the different legumes were produced as indicated in Table 4. In most countries, about 90% of the total amount of seed produced were certified seed, quality declared seed and truthfully labelled seed. Thanks to community seed producers, these amounts of seed produced were available for smallholder farmers in remote areas.

3.3 | Innovative and targeted seed marketing

Innovative approaches were adopted in seed marketing for fast and efficient seed distribution, considering farmers' preferences and farmers' purchase capacity. Sale of seed in pocket-friendly small packs proved an effective strategy for wider impact. The strategy is not only convenient, but enhances affordable seed access to farmers and is also an affordable means of testing new varieties with farmers while increasing the diversity of legume varieties accessed. The approach also provided an opportunity for private companies to expand the seed business to remote and poor hard-to-reach women farmers. The small packs approach was extensively used to enhance wider and affordable access to seed of improved legume varieties and to create the demand for new varieties. Using small and affordable packs, the project spurred the growth of private companies by supporting them to expand their distribution and marketing networks in remote rural areas through diverse market channels. For instance, in remote areas of northern Tanzania (200 km from Arusha—major city), Mr Byda, one of largest seed distributors in Manyara region saw the bean seed business opportunities. He opened more rural shops and bought mobile vender trucks which are linked to the seed companies. He sold certified bean seed in 18 market places and in public gatherings associated with churches/mosque, schools and health centres in three neighbouring districts (Babati, Hannang and Mbulu).

The use of small packs showed that farmers not only wanted new varieties, but are were also willing to pay for certified seed at affordable prices. To meet this demand, it is prudent to market the seed in affordable pack sizes, in places farmers can easily access and from vendors that farmers trust (or who may be held accountable to buyers). Since 2007, small seed packs (i.e. sizes of 0.05, 0.1, 0.25, 0.5, 1, 2, 5, 10 and 25 kg) were extensively tested by private companies in seed marketing across all crops in all the target countries (see Table 5). Although the various pack sizes have various uses depending on the legumes and contexts, the private companies indicated that 0.5 kg of bean seed and below are suitable to be marketed during promotional activities (field and open days) while 1 kg packs and above are commercially viable. Between 2007 and 2017, nearly half a million packs were marketed with more than 50% of buyers being women. Between 2015 and 2017, an average of 20% of the entire seed produced was sold in small packs of 0.5, 1, 2, 5 and 10 kg across target countries and legume crops.

The small packs approach is increasingly gaining popularity among the seed companies and smallholder farmers as the most efficient and cost-effective means of reaching more farmers with affordable quantities of seed and a wider range of preferred varieties.

3.4 | Rapid adoption and use of newly released varieties

Significant results were also achieved in the release processes of improved varieties and their adoption. During the period 2007–2017, a total of 163 varieties were released, of which, 106 varieties are still being used in production (see Figure 2), representing 65% retention. This resulted from rigorous and well-coordinated research for development which clearly focused on end-user preferences. The process was also enhanced by sound collaboration between CGIAR centers, NARS, UN-Agencies, civil society, farmer organizations, seed companies and local seed and grain dealers. Using this kind of partnership in Uganda, NABE 15 (an early maturing and market preferred bean variety released in 2010 by the Ugandan National Bean Programme) was promoted and marketed by several Ugandan seed companies. By 2017 its adoption was wider and impacts have spread to thousands of bean value actors for example, farmers and traders in Uganda and in neighbouring countries including South Sudan (PABRA, 2017; The Washington Post, 2017). In Ethiopia, four bean varieties released in 2014 and 2015 are already being produced and sold by Farmers' Cooperative Unions, public seed enterprises and individual seed producers. The use of demand/market-led approaches in both breeding and seed systems has shortened the period between release and use from 10 or more years to <3 years.

TABLE 4 Evolution of seed production (tons) across TL target countries, by crop between 2007 and 2017

Crop	2007–2010	2011–2014	2015–2017
Chickpea	129,604	334,166	6,767
Common bean	11,355	30,896	8,305
Cowpea	2,495	5,279	2,501
Groundnut	21,927	41,042	4,801

Note: Due to season overlap across countries, some seed data of 2017 were not included in this paper. Since 2015, the project was implemented in few countries or states (India) than the previous phases, justifying the lower figures in 2015–2017 than previous years.

TABLE 5 Amount of small seed packs distributed, by crop, per country, in 2007–2017

	Number of Small seed packs per crop			
Country	Chickpea	Groundnut	Common bean	Cowpea
India	16,622	11,460	–	–
Ethiopia	424	–	176,858	–
Tanzania	45	–	143,045	–
Nigeria	–	11,500	–	75,885
Mali	–	6,740	–	17,300

Note: –: Country not targeted for the crop.

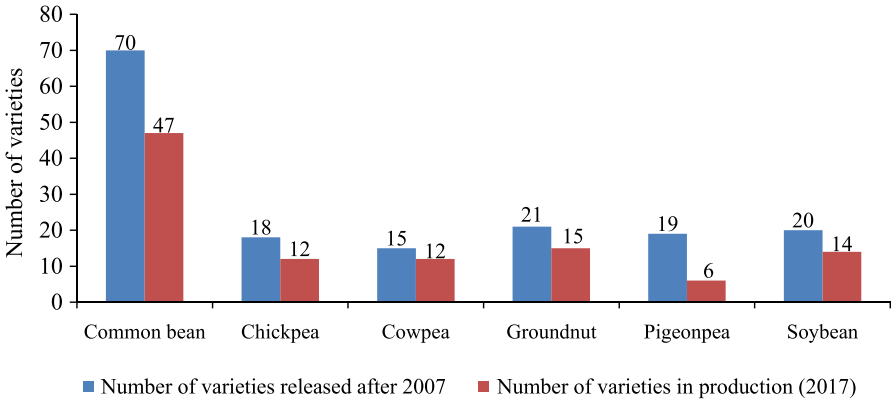

FIGURE 2 Number of varieties released in TL II countries after 2007 and those in production, by crop

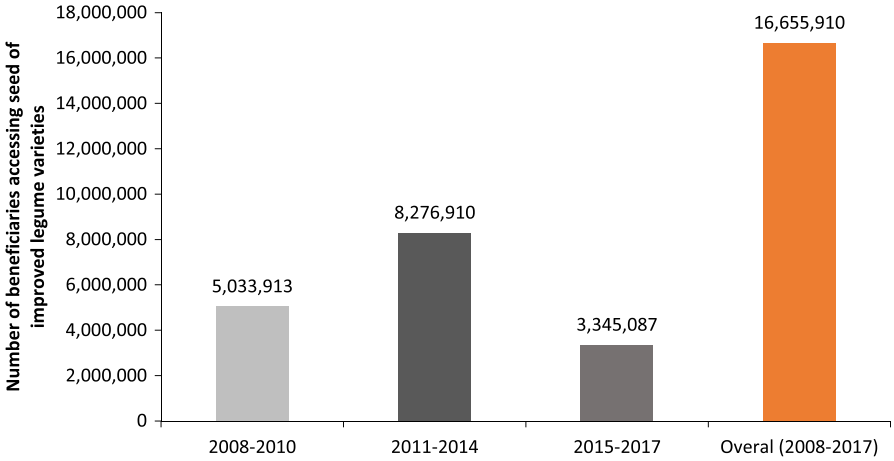

FIGURE 3 Seed access across TL III countries across crops between 2007 and 2017

3.5 | Enhanced access to legume seed

The concerted efforts invested in developing and implementing the seed delivery models showed impressive results in terms of access to high-quality legumes seed of user-preferred varieties. Between 2007 and 2010, more than 5 million farmers received high-quality seed of one or more improved legume varieties. Between 2011 and 2014, collaborative efforts were stepped up enabling more than 8 million smallholder farmers to access seed, indicating a 64% increase in the number of beneficiaries from the previous period; while in 2015–2017 period, despite reducing the number of crops to four and countries to eight, more than 3 million smallholder farmers accessed quality seed of improved legume varieties. In total, more than 16.6 million smallholder farmers, (61% of them being women) accessed seed of improved legume varieties in TL project countries between 2007 and 2017 (Figure 3). Studies on adoption showed significant increase in the income of beneficiaries. In Nigeria, for example, adoption study conducted on cowpea varieties showed an increase by 49% in the project sites.

3.6 | Increased productivity of legume grains

With the adoption of improved varieties and associated technologies, productivity of legume grains significantly increased in different countries (Figure 4). In Ethiopia, the bean and chickpea productivity increased by 52% and 37%, respectively, while groundnut productivity increased by 38% in Tanzania. The concerted efforts and positive policy support from Government of India that encouraged farmers to grow more pulses using quality seed and other inputs led to enhanced production (22.95 million tons) of pulses in India during 2016–2017. Three districts (Hamirpur, Banda and Chitrakoot) were covered under TL-III project for popularizing quality seeds of high-yielding chickpea varieties and higher area was sown with quality seed of chickpea resulting in higher productivity.

4 | DISCUSSION

Except pigeonpea that recently saw its hybrid variety released, most legume crops are self-pollinating (Kaoneka et al., 2016; Saxena, Kumar, & Tikle, 2013). The self-pollinating nature allows farmers to save their own seed with little yield penalty if they pay attention to quality. Combined with high seed rates required for legumes, this becomes a major disincentive for the profit-driven private sector to invest in legume seed business. On the contrary, emerging seed companies in Africa focus on lucrative maize hybrid seed business that offers repeat sales (Mabaya, Omanga, & DeVries, 2013). Interest in legume seed business is increasing because of increased demand for legume grain and products in the domestic, regional and international markets.

Collaborative and market-led approaches are keys to achieving impacts if used in legume variety promotion and seed dissemination.

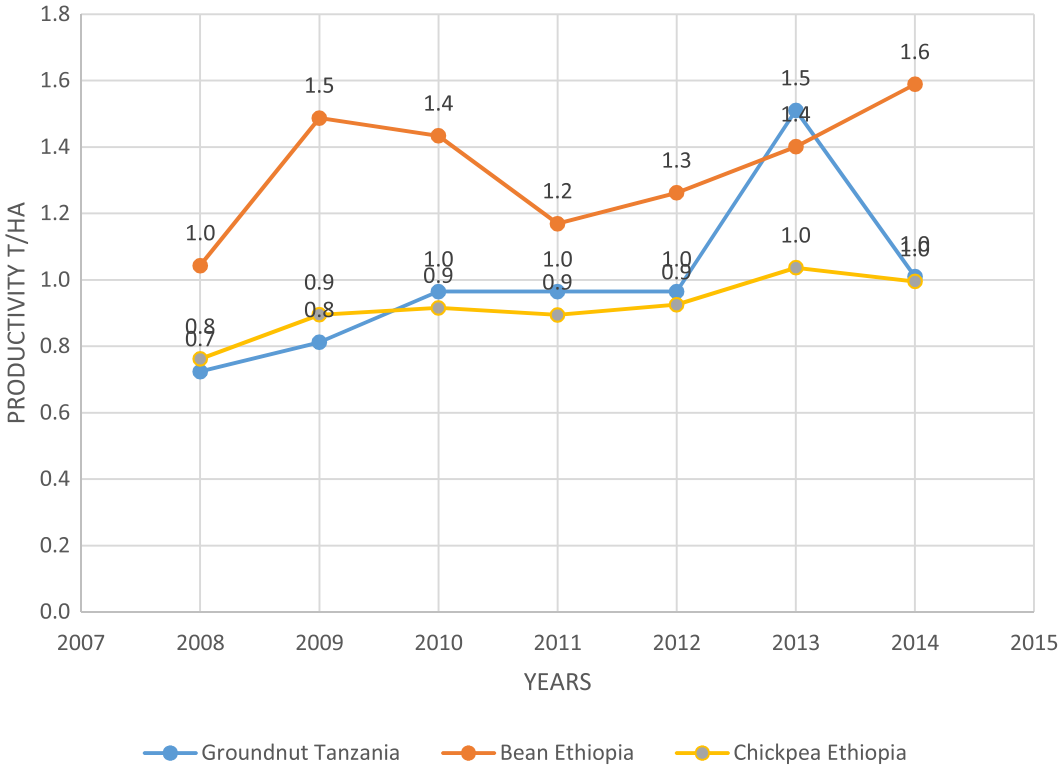

FIGURE 4 Major legume productivity in some TLIII countries (source FAO, 2016)

For instance the use of participatory variety evaluation and selection and demand-led breeding approaches in common bean (Almekinders, 2011; Buruchara et al., 2011) facilitated the release of farmer-demanded varieties whose seed demand was higher than it used to be. Small scale farmers' access to quality seed of improved varieties is often constrained by poor proximity to high-quality seed sources, thereby limiting their access. Asymmetry of information flow about availability of improved varieties, insufficient amounts distributed, high purchase price, poor technical knowledge, non-membership of farmer organizations and punitive regulatory frameworks work in concert to limit farmers' access to high-quality seed (Akpo et al., 2014). Embracing innovative partnerships that enhance market access and feedback in variety development and dissemination increase adoption and impacts. The use of participatory variety selection such as variety ranking by farmers can be used to foster acceptance and adoption thus reduce wastage of resources by developing varieties which probably might be rejected by farmers (Odhiambo, Ngigi, Lagat, Binswanger, & Rubyogo, 2016). The participation of farmers, seed producers and grain traders during the variety selection, release ceremony and subsequent promotion has proven significant in identifying both variety agro-ecological adaptation and market suitability (Singh et al., 2014). During the past 10 years the Tropical Legumes Project has been working to improve market orientation in variety development and dissemination to enhance legume variety adoption.

In most countries, various categories of actors were involved in seed production and dissemination to smallholder farmers. The diverse stakeholders currently making a living out of seed business is a good indication of the grassroots works conducted to lay the ground for sustainability. Even the smallholder farmers in remote areas are not left behind as it is the case when public sector and few seed companies were the main players in production and supply. A good example is Amwari Seed Company (Plc), born out of a farmers' seed producer group in Adaa District in Shewa Region of Ethiopia (Ojiewo et al., 2016).

Co-investments by partner development organizations and decentralized seed businesses significantly contributed to accessing quality seed beyond the "traditional" high potential zones thus expanding seed access to the often overlooked smallholder farmers in remote areas. This is an indication of the success of the approaches and methodologies that were designed and implemented. For sustainable seed systems development, approaches that prioritized partnerships, targeted the end users and where the roles and responsibilities of all players were clearly defined guided the process (Christinck, Diarra, & Horneber, 2014; Rubyogo et al., 2010). More importantly, engaging the private sector particularly seed companies, individual seed entrepreneurs and farmer organizations provided a foundation for sustainable seed systems (CABI, 2014). Conducive seed business environment would unleash the potential role of the private sector in promoting seed systems development in SSA. From the project experience and lessons learnt, some of the major steps to catalyze private sector investment in legume seed included (a) aligning seed systems to grain and value-added product demand, (b) identification of appropriate varieties, (c) variety demand creation through multimedia means including village-based variety demonstrations through public and private partnership, (d) bundle seed supply with complementary

inputs and support services to increase productivity and reduce risks for example, seed dressing, crop insurance, adapted farm mechanization, (e) support seed companies to establish distribution networks including mobile seed sale by local agro-dealers as it is happening in northern Tanzania with bean seed, (f) develop transparent and impact-oriented license agreement with seed companies since few of them invest in legume breeding, (g) expand the use of affordable pack size for legume seed, (h) build seed production and commercialization capacities of the emerging bean seed enterprises. Catalyzing private companies to engage sustainably in legume was achieved in Malawi using some of the above elements (Mugendi, Waswa, Mucheru-Muna, & Kimetu, 2011; Rubyogo, Magreta, et al., 2016a) and Tropical Legumes Project learnt and borrowed from these initiatives. Private sector role can be further developed through enhancing their complementarity with the public sector, for example, taking full charge of breeder and foundation seed production. The promotion of complementary yield boosting technologies (i.e. seed priming and dressing) that enhance the use of fresh seed of improved legume varieties over recycled ones is an effective mechanism to grow farmers' interest in seed and variety replacement. For instance, a wider testing of Apron Star (a seed dressing fungicide, insecticide and root growth enhancer) on beans in Tanzania showed a yield increase between 20% and 50% (PABRA, 2018). This contributed to the increased demand of certified bean seed since farmers got access to multi technologies and increased the bean yield (J.C. Rubyogo, 2018 personal communication).For sustainable legume seed sector development, we need to foster interventions beyond seed. It is a common knowledge the seed market cannot stand alone but is influenced by the grain market. Working along the commodity value chain will significantly contribute in expanding the legume seed business. A strong business partnership involving close ties through formal contracts with traders, processors, warehouses and export markets will expand the grain market of improved legume varieties. This would translate into seed market and subsequently incentivize farmer and the private sector to invest across the value chain, that is, from other relevant inputs to seed through the grain and byproducts that are largely marketed for various human and animal uses (PABRA, 2018).

Despite additional costs related to packaging (i.e. materials and labour), the use of small packs has been more than successful in all countries and for all crops. Additional costs related to packaging is compensated for by many benefits, among them, increased seed sale, wider seed coverage, including penetration in hard-to-reach areas, introduction of new and multiple varieties and seed access to poorer farmers including women. When new varieties are packed in small packages even to about 0.5 kg, farmers can easily try the variety at an affordable price (McGuire & Sperling, 2016). Since the smallholder farmers grow legumes on small acreage (up to half a hectare) in SSA, the small seed packs (1, 2 and 5 kg) rather than the traditionally commercialized ones (25, 50 and 100 kg) contributed to making quality seed available based on the smallholder farmers' purchasing power and average legume acreage. Meeting the seed demand of improved legume varieties is still a challenge as a result of lower productivity of legume crops and lower capacity of public and private seed companies. Thus, there is a need to promote yield enhancing technologies and labour saving in legume seed production to meet the seed demand and cut the cost of production and marketing (Katungi et al., 2011).

The different efforts made to bring existing legume technologies to the knowledge of various investors (actors) including farmers also made a huge difference. Demonstrations, fields, radio and TV programs, seed fairs and agricultural shows and trainings permitted to a larger number of stakeholders and smallholder farmers to be aware of the technologies and self-appreciate their performance in their own field (Mugendi et al., 2011). Smallholder farmers in SSA operate in so diverse and challenging environments that one variety or one legume crop rarely fits in their farm and livelihood diversity. The approaches used in the project interventions have been innovative to avoid such pitfalls through decentralized seed production (QDS&TL) to get quality seed of improved varieties to the door step of the end-users, the resource-poor farmers in remote areas. The different trainings organized for smallholders and the linkage among value chain actors along the different commodity value chain was also impactful on the process of adoption and use of the legume varieties promoted (Walsh, Remington, Kugbei, & Ojiewo, 2013). The training sessions on legume pre- and postharvest management including business management also enhanced skills and knowledge of value chain actors. Through the Tropical Legumes Project work, we proved that the disadvantage of legume crop to attract private seed companies (being self-pollinated) can be overcome if well-thought-out tailored approaches are used in the dissemination of quality seed of improved variety to smallholder farmers in SSA and SA.

Marked-led approaches to legume seed dissemination have shown significant results on farmers' uptake of varieties and subsequent improvement in their livelihood as it has been proven on legumes (Ahmed, Mesfin, Abady, Mesfin, & Kebede, 2016; Rubyogo, Magreta, et al., 2016a). Beyond legumes, similar findings have been reported for tuber and roots, for example, cassava (Afolami, Obayelu, & Vaughan, 2015), cereals, for example, rice (Ouma, Bett, & Mbataru, 2014), maize (Awotide, Diagne, & Omonona, 2012). Rahman and Luthfa (2004) also reported the positive farmers' response to seed production as seed trade grows.

The different indicators used to show the effectiveness of our approach largely match the indicators of The African Seed Access Index (TASAI) for assessing seed systems performance (see TASAI, 2017). The capacity building activities for breeders and other stakeholders, the number and diverse varieties made available for the users, basic seed availability, public and private seed companies' involvement, agro-dealers engagement, use of alternative seed certification scheme and seed loan activities embraced are good indications.

5 | CONCLUSION

Resource-poor farmers are ready to adopt new, improved varieties of legumes. However, only a full package of variety, complementary

technologies and innovative seed delivery models will achieve the desired impact for better food and nutrition systems. Furthermore, an efficient seed system for delivering varieties must be linked to the commodity value chain. Developed grain markets are an obvious driver of seed demand through which the need for productivity is justified—but deliberate efforts must be put into creating working linkages between the markets and seed/grain producers. Also, seed delivery systems may intrinsically be region- and crop specific. Therefore, a pluralistic approach will allow us to identify the best bets, especially when enabled by policies that recognize seed outside the certification scheme. The recognition of QDS contributed significantly to access to quality seed of improved legume varieties and shortening the lag time between variety release and their adoption by farmers. Investments should be made towards creating demand for new varieties and complementary technologies. The multi-stakeholders approach enhances efficiency and effectiveness in technology promotion. Diversification of seed sources by linking formal and informal seed systems is also a fundamental tool to enhancing seed access to resource-poor farmers especially those in remote areas.

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CONFLICT OF INTEREST

On behalf of the authors, I declare that there is no single conflict of interest in the publication of this article.

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