

An integrated seed delivery system and seed research in Kenya: Case studies of pigeon pea, onion and dry bean

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Producing adequate and nutritious food for a population estimated to reach a billion people is the main challenge facing African countries in the twenty-first century. This demands increased utilisation of technologies designed to enhance crop productivity and quality, especially considering predictions in climate change and variability. Crop productivity is constrained by biotic and abiotic stresses, and by socio-economic factors, especially timely availability of affordable seed of improved varieties. The main limitation is a lack of integrated seed delivery systems linking key players in the seed value chains of most crops. Universities are key players in this system, a position recognised by recent policy change for Kenyan universities as described in the Universities Act (2012). The development of more than 18 new pigeon pea, onion and bean cultivars and of a seed delivery system at the University of Nairobi over the past two decades illustrates the potential of and challenges for implementing an integrated seed delivery system and defining the role of universities. This paper describes the current seed delivery system in Kenya, and proposes an integrated and sustainable seed delivery system and the functions of the key actors.

Keywords: seed systems, universities, varieties

Introduction

The principal challenge for African nations in the twenty-first century is to feed a growing population, estimated to reach over a billion people. During the last two decades of the twentieth century, only Africa recorded a decline in per capita food production, which was attributed to a rapid growth in population and a decline in agricultural production. For example, Kenya recorded one of the highest population growth rates, at nearly 4% in the mid-1980s and early 1990s, but it has now stabilised at about 3% in the past decade. The decline in agricultural production was associated with several biotic, abiotic and socio-economic factors. These include inability to replenish declining soil fertility, use of inferior and poor quality seeds, drought, inability to control heavy yield losses due to pest and disease attacks, limited access to and participation in local, regional and international markets, lack and/or poor implementation of supportive policies to boost agricultural production, and poor infrastructure. The result of the decline in production and rapid growth has been extreme poverty in some regions, widespread malnutrition, reliance on food aid and environmental degradation. However, in the past decade several African countries have registered impressive economic growth of more than 5% per annum, reduction in poverty and improved nutrition as a result of interventions by governments and development partners.

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Predicted food situation

It is predicted that between 1997 and 2020, Africa's population will double to 1.1 billion. The demand for imported food (mostly cereals and legumes) will increase to 50 to 70 million tonnes (t) per year (Kimani and Kirkby, 2002). If the current situation persists, it is unlikely that food deficit nations will have the resources to purchase this huge volume of food on a commercial basis. Several countries have become regular recipients of food aid. To avoid a possible human catastrophe, it will be necessary to accelerate development and to implement strategies designed to increase productivity and commercialisation.

Major food crops produced in arable regions of Kenya include cereals, legumes, vegetables, root crops and fruit crops. Major cereal crops include maize, sorghum and millet. The main legumes, in declining order of importance, are bean, pigeon pea, cowpea, green gram and chickpea. Main root and stem crops include potato, sweet potato and cassava. Major vegetable crops include tomato, onion, cabbage and kale. These crops are grown by small-scale, resource-poor farmers for domestic consumption and income generation.

Low productivity has been attributed to several biotic, abiotic and socio-economic factors. Production is based on traditional varieties, which have low yield potential and are susceptible to common diseases and pests. Losses due to diseases and pest in the field and during storage are heavy, but severity of attacks varies seasonally. Due to continuous cultivation, an inability to replenish nutrients and a poor nutrient base, fertility has continued to decline. Soils are generally low in nitrogen and phosphorus. Moisture stress further reduces their productivity especially in arid and semi-arid (ASAL) regions due to the unreliable and low amounts of rainfall, low moisture retention and heavy losses due to evapotranspiration. Loss of ground cover due to drought and heavy grazing has exposed land to erosion and further degradation. In some ASAL areas, land has been lost to deep gullies, which are difficult to reclaim. Population pressure has led to fragmentation of land into small, hardly economical subunits.

Several socio-economic factors have also contributed to declining productivity. Although improved cultivars of several crops have been developed in the past two decades, their impact has not been realised because of inefficient, unreliable and often non-existent seed delivery systems. Seed companies have tended to focus only on a few crops produced for high-potential zones, where effective and reliable markets exist. Most companies produce and distribute maize, and to a lesser extent beans and other grain legumes. Because of the poor infrastructure, seed is delivered only to urban and shopping centres in more accessible areas. Seeds are often of low quality and are delivered late in the season.

Influences on seed delivery systems are not always socio-economic; sometimes they are technical in nature. For example, some crops, such as onions, carrots and other vegetables, may require vernalisation to stimulate flowering. This has constrained production of seed under the prevalent warm, tropical conditions in Eastern Africa. Furthermore, there has been limited breeding and seed science research in this region. Consequently, farmers have relied on imported and often expensive seed, e.g., for onions, runner beans, snap beans and other vegetables.

Breeding research is often poorly connected to the end users. As a result, improved varieties do not have the desired impact at the farm level. The main constraint is the lack of an effective seed delivery system capable of producing and disseminating adequate certified seed. Most Kenyan farmers still

use seed varieties that are more than 20 years old. There is a need for better links between researchers and users – not just discoveries, but innovations that are actually used.

Implications

Improved cultivars and a seed delivery system can only be part of the solution. In this paper we focus on seed delivery systems, and highlight three case studies of seed science research in Kenya.

Seed delivery chain and variety development in Kenya

A seed delivery chain can be defined as the integration of all activities, processes and actors involved in production, bulking, processing, labelling, storage, dissemination, promotion and marketing of seed or other planting materials to end users. The key elements of seed delivery include variety development and release; production of nucleus, breeder, pre-basic, basic and certified seed and other classes of seed; quality assurance, seed processing, storage and conditioning; promotion, distribution and marketing; variety maintenance; monitoring demand; and the overall coordination of activities and actors. The actors may be individuals, groups of individuals, institutions, public and private companies along the seed value chain, who provide the services or products, and the consumers of the end products.

Variety development

Variety development in Kenya is carried out within public institutions and private companies. The main public institutions involved in cultivar development are the Kenya Agricultural Research Institute (KARI; since renamed the Kenya Agricultural and Livestock Research Organization) and public universities. Private universities do not usually conduct breeding research. In 2012, the government enacted a new policy for public universities. There is an increasing demand on universities to play a more active role in national development – outside their traditional teaching and research roles (NACOSTI, 2013). This demand is known as the ‘third mission’ of universities. To achieve this mission, their interaction with industry, communities and policymakers has become ever more crucial, and efforts are now being made to make the universities occupy a more central place in the national innovation system. A few crops – maize, sorghum, millet, bean, pigeon pea, cowpea, chickpea and green gram – illustrate the variety development process in Kenya.

Improved maize varieties

Maize is the most important staple crop in Kenya and has the highest number of new releases (10-20) per year. Development of improved cultivars has been based on agro-ecological zones. The Kitale Programme, which started in 1955, focused on developing long-duration varieties for high altitude zones with a long growing season and high-input systems. This programme released the first synthetics soon after independence in 1964 (such as Kitale Synthetic I, II, III and IV) and hybrids (Harrison, 1970). However, the hybrid became so popular that synthetic production was stopped. Kenya’s leading 600 series hybrids, such as H612, H613, H614, H625 and H628, were developed at the Kitale Station. The Katumani programme was started in 1957 to develop short-duration, drought-tolerant varieties for semi-arid areas. The popular, short-duration Katumani composite B and, later, Makueni composite were developed from this programme. Hybrids for the medium-altitude zone were developed at the Embu programme, which started in the 1960s. They were crosses between the late maturing Kitale hybrids and early maturing Katumani composites. The best known hybrids from this programme are H511 and H512. Breeding maize for the hot, humid and disease-prevalent coastal lowlands started at Mtwapa in 1975. Important varieties developed from this programme include the Coast composite and Pwani hybrid. Although these improved varieties are widely grown in the

country, farmers also have made selections from the Kenya Flat White complex. This population originated from natural crosses and mixtures among introductions made since the sixteenth century from Caribbean maize such as Cuzco and Caribbean Flint by the Portuguese traders and settlers from South Africa and Zimbabwe early in the twentieth century (Harrison, 1970). Distinct varieties, such as Ukambani local, Katumbili, Githigu and Muratha, were selected by farmers from the complex. Although many new varieties have been released since 1992 when the market was liberalized, older-generation hybrids, composites and farmers' varieties still dominate the seed delivery system in Kenya, partly due to the slow adoption of new varieties.

Improved sorghum and millet varieties

Development of improved sorghum varieties started in 1948 at Ukiriguru in Tanzania, and later at Serere in Uganda under the East African Agricultural and Forestry Research Organisation in 1958 (Dogget, 1970). In Kenya, sorghum improvement was initially based at Alupe and Kakamega in western Kenya and later at Katumani, starting in 1978. The main varieties developed from these programmes were Serena, Seredo, Dobbs Bora and Lulu. A new variety, Mtama 1, was developed and released through a collaborative programme between the Kenya Agricultural Research Institute (KARI), Katumani and the regional programme of the International Crops Research Institute for Semi-Arid Tropics (ICRISAT). Work on improvement of millet started recently at Katumani.

Improved bean varieties

Bean is a preferred crop for farmers because of its short growth cycle (90 days and less), resistance to drought and ability to mature on residual moisture. Kenya has the largest areas under bean cultivation in Africa, estimated at over 670,000 ha (Wortmann *et al.*, 1998) and more recently, 1 million ha (MOA, 2012). Common bean is the most important grain legume. Its improvement started in 1977 at the University of Nairobi (UON) as part of the Bean Cowpea collaborative research support programme (CRSP). The Grain Legume Project (GLP) at the National Horticultural Research Centre, Thika, based partly on the materials developed at the UON, started in the late 1970s. At Katumani, breeding activities started in 1980 as part of a Food and Agriculture Organization (FAO)/ *United Nations Development Programme (UNDP)* grain legume project. Breeding activities in Kenya expanded considerably with the formation of a regional network led by the International Center for Tropical Agriculture (CIAT) in 1985. The main objective of these programmes was to increase productivity through developing bean cultivars tolerant to biotic and abiotic stresses.

Several varieties have been released from these programmes. Six cultivars were released by the GLP in 1984. These were GLP 2 (Rosecoco or Nyayo), GLP 24 (Canadian Wonder), GLP 1004 (Mwezi Moja), GLP X-92 (Mwitmania) and GLP 585 (Wairimu, or Red haricot). Of these, Mwezi Moja and GLP X-92 were recommended for production in semi-arid areas. The sugar beans were also recommended for production in semi-arid regions. The Katumani programme released three cultivars in 1998 (KAT B1, KAT B2 and KAT B9). Another two cultivars, KAT X-56 (large red kidney) and KAT X-69 (a red mottled) type were released in 2001. KARI-Kakamega in collaboration with CIAT has released three bush cultivars tolerant to root rot (KK 8 or SCAM 80/15 CM, KK 15 or MLB 49-89a; KK 22 or RWR 719) which are adapted to western Kenya. Four early maturing sugar bean cultivars (Miezi Mbili, Kenya Early, Kenya Speckled Sugar and New Rosecoco) were subsequently developed by the UoN Bean Research Programme and formally released by the National Variety Release Committee (NVRC) in 2008 (Table 4). UON's improved bean germplasm has been shared with over 33 countries in Africa, Asia, Australia, Europe, North and South America.

Improved pigeon pea cultivars

Pigeon pea is probably the most drought-tolerant grain legume grown in the semi-arid regions of Kenya. Often, it is the only thriving crop after severe droughts from which a harvest can be made. Pigeon pea improvement started in 1977 at the University of Nairobi and in 1980 at the National Dryland Farming Research Center, Katumani (Kimani, 2001; Kimani *et al.*, 2001). The first improved cultivar, NPP 670, was released in 1983 (Jones *et al.*, 2001; Mergeai *et al.*, 2001). It became popular among farmers because it is early maturing, tolerant to drought, short in stature and determinate, and has the preferred large, white/beige seeds (Kimani, 1990). KAT 60/8 and ICPL 87091 were released in 1998. KAT 60/8 is of medium duration and indeterminate. ICPL 87091, originally developed by ICRISAT, is an early maturing and determinate variety. Another three cultivars have been recommended for release by the collaborative programme among KARI, University of Nairobi and ICRISAT. These are ICEAP 68 (medium duration), ICP 6927 (medium duration) and ICEAP 40 (long-duration and resistant to wilt) (Kimani *et al.*, 2001).

Improved cowpea cultivars

Cowpea is grown by farmers in semi-arid areas as it is drought-tolerant. Its leaves are also consumed as a vegetable. Cowpea improvement in Kenya started in 1977 as a collaborative programme between the Ministry of Agriculture and the University of Nairobi/Cowpea-Bean CRSP project. Cowpea improvement at Katumani started in 1980. Two important varieties were released from these programmes, Machakos 66 (M66) and K80. M66 is a drought-tolerant, indeterminate, dual-purpose cowpea variety adapted to areas above 1,300 m. It gives an average yield of 1.3 t/ha. K80 is semi-spreading and drought-tolerant. It is best adapted to low altitudes (<1,300 m) and gives an average yield of 1.5 t/ha.

Chickpea and green gram

Although chickpea and green gram are important in the semi-arid areas of Kenya, limited work has been done to improve their productivity. Field experiments showed that green gram (also known as mung bean) is more drought-tolerant than cowpea. A small improvement programme was started at Katumani in 1980. KVR 26 was selected for its high-yield, determinate-growth green gram cultivar with large seeds (60.3 g/1000 seeds). It has since been released. Work on chickpea started early in 2000 in a collaborative programme between ICRISAT and KARI. ICCL 83110 was selected and recommended for release because of its high yield and tolerance to wilt and pests.

Delivery systems

Seed delivery systems operational in Kenya can be grouped into four categories: formal, informal, seed aid and mixed.

Formal seed systems

This category refers to the production, processing and packaging, labelling and marketing of certified seed by registered producers. This normally involves private or public seed companies with outlets in many parts of the country. Leading seed companies in Kenya include the Kenya Seed Company, East African Seed Company, Western Grain and Seed Company and Faida Seeds. Several multinational companies such as Syngenta, Bayer (East Africa Ltd), Seminis, Cargill, Pannar and Royal Sluis have started operations in Kenya directly or through subsidiaries. There are about 70 registered seed companies in Kenya, many of which are members of the Seed Trade Association of Kenya (STAK) based in Nairobi. Most of these companies produce seed of cereals, (especially maize, wheat

and barley) and legumes (especially bean) which are under mandatory certification (schedule II crops), and distribute imported vegetable seeds. These companies have country-wide distribution networks and offer modest national coverage. Except for maize, they account for less than 5% of the seed sown in ASAL areas. Very little certified seed of pigeon pea, cowpea, sorghum, millet or green gram is produced by private seed companies. With the exception of cut flowers, companies do not produce planting material of most vegetatively propagated crops. Private companies are profit driven and consider demand for the seed of other crops unreliable and expensive to produce and market. However, demand for seed of various crops is poorly documented. An issue often raised by seed companies is that, for self-pollinated crops, farmers will buy seed once and use farm-saved seeds in subsequent seasons. But the key question is why farmers save seeds for future planting or buy grain in open markets for use as seed. Farmers save and reuse seed because they are not assured of regular, timely availability of seed locally. This is a vicious cycle. If farmers were assured of timely availability of affordable quality seed near their locality, they would probably dispose of their produce and buy seed each season, as they do for crops such as maize. Studies have shown that farmers are willing to buy seed of self-pollinated crops such as beans at twice or more the grain price (Sperling *et al.*, 2004; Rubyogo *et al.*, 2007). A formal seed system is sustainable but tends to produce more expensive seed because of the additional certification and marketing costs.

Informal systems

This category refers to the production, processing, marketing and/or distribution of seed by unregistered seed producers. Seed produced is variable in quality and is not produced under a certification scheme. Production and marketing are often localised and based on low-input technology. Key players in this system include NGOs, farmers, farmer groups, researchers and community-based organisations (CBOs). In Kenya, this system has been producing seed of open-pollinated varieties of cereals, grain legumes and also of vegetatively propagated crops such as sweet potato and cassava for many years. Except for schedule II crops, no certification is required, although the situation is changing in favour of certification of more crops. It accounts for over 90% of the seed of most crops planted each season. Because it is based on rainfed cropping systems, it is highly vulnerable to drought stress, occasioning severe shortage of seeds. Producers have limited access to breeders' and basic seed of improved varieties. The quality of seed is variable because there is no independent verifiable quality assurance process. However, it has potential for sustainability partly because it is derived from the traditional system and has limited demand for external inputs. It also offers opportunities for evolution into indigenous seed companies.

Seed aid

Also known as emergency seed, this is a relatively new development in Kenya, which started in 1992 as an effort to supply seeds to communities faced with acute seed shortage following drought-related stress. Seed aid started as a collaborative programme involving the government, NGOs, CBOs, farmers and other development agencies. In the past decade, considerable quantities of seed maize, bean, cowpea, sorghum, pigeon pea and green gram were acquired from seed companies or produced by communities for wider distribution. Although this was intended to be a limited, one-time intervention, it has become a regular source of seed for the affected communities, creating a dependency syndrome. Operations of seed aid are poorly linked with the formal research system. A survey evaluating the effectiveness of seed aid in Kenya found that both the government and NGOs delivered seed mainly of maize and beans, with smaller amounts of drought-tolerant crops such as cowpea, sorghum, millet and pigeon pea (Sperling *et al.*, 2004). Maize and bean were the priority seeds for the

majority of farmers, even in situations where they were less adapted. Farmers expressed discontent with the timing (generally late), targeting (not transparent) and quantities received (too little). Often the wrong varieties were delivered. For example, seed of long-duration hybrids such as H614 was distributed to farmers in semi-arid districts. There was no evidence that seed aid *per se* strengthened farmers' systems, and it is a costly intervention for farmers, governments and development agencies.

Mixed systems

This is a seed delivery system that combines elements from both formal and informal systems. It is operated by small seed companies and/or commercially oriented individual seed producers. They may or may not be registered. Part of the seed is produced locally under a certification scheme or imported and packaged locally. Such producers may provide seed for emergency aid, often by cleaning, dressing and packaging commodity that was not intended for use as seed. They have limited distribution capacity.

Developing and promoting an integrated seed delivery system

A wide range of improved crop varieties has been developed in Kenya. However, most have not reached their intended beneficiaries because of the lack of an organised seed delivery system. Because of the limited information available, often the wrong varieties are recommended to farmers, especially during emergency situations. Little promotion work has been carried out, and so few farmers and development agents know about improved varieties. Sometimes farmers may be aware of the improved varieties but do not know where to obtain the seed. This has contributed to low productivity reported in many regions.

To overcome the limitations associated with the current seed delivery systems and improve the availability of seed to farmers, we propose an integrated system with eight major components based on the seed value chain approach.

These are:

- variety development and testing;
- seed multiplication;
- quality assurance;
- promotion;
- distribution and marketing;
- variety maintenance;
- storage;
- monitoring and coordination.

This integrated system requires different actors at different stages, all of whom should be coordinated. Although most of the components exist in the current seed delivery system, there is very little vertical or horizontal integration, which reduces the effectiveness of the system. There is hardly any monitoring and coordination of activities of actors or clear delineation of responsibilities. Suggestions are made below on how these components can operate.

Variety development and testing is the primary source of improved varieties. This activity should be the responsibility of the national research organization, public universities, international centres and, to some extent, seed companies. They have the capacity, human resources, skills,

physical facilities and access to international genetic resources of many crops. They are also capable of producing high-quality breeder and basic seed for sale to companies and other seed producers on a regular basis. Necessary legislation for this activity is in place, and was revised recently to cater for a liberalised seed industry.

Seed multiplication is probably best carried out by seed companies, small independent producers or those contracted by seed companies. Few smallholder producers can be expected to meet the stringent, mandatory requirements legislated for the production of certified seed for crops. Informal producers, NGOs and other development agents have played key roles in seed multiplication, especially for areas that were not well served by seed companies. However, seed produced by unregistered seed producers is not certified. Consequently it is recommended that basic and breeders' seed is produced by breeders or their institutions; certified seed is produced mainly by seed companies; and standard seed is produced by farmers, NGOs and CBOs. This is consistent with the harmonised regulations for the seed industry being promoted by the Eastern African Community and ASARECA.

Provision of high quality seed is an important component of an effective seed delivery system. Standards for quality seed, such as cultivar purity, germination capacity and moisture content, have been developed. This service, previously provided by the National Seed Quality Control Service (NSQCS) under KARI, is now a mandate of the Kenya Plant Health Inspectorate Service (KEPHIS). KEPHIS is responsible for seed certification in Kenya and provides internationally recognised seed certification and phytosanitary services. It conducts multi-location national performance trials (NPTs) to validate the performance of candidate varieties submitted by public and private breeders. KEPHIS also organises meetings for the NPT Technical Committee and the National Variety Committee on behalf of the Ministry of Agriculture. It maintains a register of released varieties and post-control plots, inspects seed crops, issues labels for certified seed, and regulates seed exports and imports in accordance with the *Seeds and Plant Varieties Act* (Chap. 326) – which was updated in 2006 and 2013 to maintain relevance to a rapidly changing seed sector. It is expected that the seed offered to farmers will be of the highest quality and will meet international standards.

Promotion of improved varieties is critical if growers are to provide a reliable market for seed producers. Limited promotion activity for the improved varieties has been carried out in Kenya. Most activities have focused on maize seed. Consequently, few farmers are aware of the availability and potential of varieties of other crops. Adoption has been slow. Seed should be regarded as any other commercial product. Demand is created by promoting a product. Many seed companies have argued that there is no demand for seed to justify production of the seed of grain legumes, traditional cereals and vegetable crops. Few of these companies have attempted any significant promotion campaign. Available evidence indicates that farmers purchase as much as 50% of their seed requirements from local markets, even for self-pollinated crops such as bean (Sperling *et al.*, 2004). Promotion can be done through multiple channels such as on-farm trials, demonstrations, electronic and print media, field days, bazaars or community meetings, church announcements, and drama. Materials required for promotion should be well designed and informative. These include posters, leaflets and brochures for farmers and extension agents. Promotional activities require effective and functional partnerships among researchers, extension agents, NGOs, CBOs, farmers, community leaders, traders and stockists.

An effective distribution network is essential to ensure seed reaches farmers at the right time, in adequate quantities and in good condition. Such a network should involve seed companies, NGOs,

transporters, CBOs, farmer seed producers (or small-scale seed enterprises), and traders to serve communities in each of the target areas and others with suitable storage capacity. Delivery schedules should be worked out to ensure seeds are available before planting time. The costs of distribution and margins for the various players should be factored in during the development of price structures.

Except for maize, few breeders (or their institutions) maintain breeders' seed of released varieties because of the high costs involved. Most of the improved varieties have been developed through short-term research projects. In addition, there is no regular demand from potential seed producers. In a liberalised seed industry, it is expected that breeders and/or their institutions should finance their variety maintenance activities from the proceeds of breeder and basic seed to commercial seed producers. Maintenance breeding is important if seed producers are to be regularly assured of high-quality breeders' and basic seed. Contracts between seed producers and breeders are required to remove uncertainties associated with the production of seed, which cannot be disposed of.

Seed must be stored in good condition for variable duration after harvest to facilitate distribution to retail outlets and for sale to farmers for planting. The quantities stored will vary with the estimated demand in the target regions. Suitable storage facilities should be provided in an integrated seed delivery system. Seed may be stored to meet the regular demand by growers, or as strategic reserves. Storage of strategic reserves to meet unexpected shortages or to meet the needs of marginalised sectors of society is expensive, and is beyond the scope of private seed producers. The government should contract private companies to maintain strategic reserves based on anticipated demand.

Finally, an integrated seed delivery system cannot operate effectively unless there is a functional coordinating and monitoring unit. The functions of such a unit would be to provide a continuous situation analysis, monitoring levels and status of normal and strategic reserves, unblocking bottlenecks in the delivery system, and providing a consultative forum for planning and implementation of agreed activities by stakeholders. Such a unit should have wide representation, including policy-makers, seed producers and merchants, and local and international organisations involved in the seed trade.

Case studies

Pigeon pea seed production

After the development and release of NPP 670 variety in 1983, the next challenge was to develop a seed delivery system (Kimani, 1990). Several seed production and dissemination pathways were evaluated. These included a revolving fund scheme operated by the Pigeon Pea Research Programme; production and dissemination of seed by contracting farmers by the Machakos Integrated Development Project (MIDP, 1984–90); farmer-to-farmer; extension officers; ICRISAT/KARI seed projects; supporting farmer seed entrepreneurs in Mbeere, Machakos and Kitui districts (now 'counties'); and private seed companies such as the East African Seed Company, which has expressed some interest. Of these, support for farmer entrepreneurs in Mbeere district was the most successful, effective and sustainable seed delivery pathway (Kimani and Mbatia, 1993; Kimani *et al.*, 1994a,b). NPP 670 was introduced to Mwea division, Mbeere district during a field day in Karaba location in August 1986. The field day was organised in a farmer's field (Mr Joseph Mugweru) by the Pigeon Pea Research Programme of the University of Nairobi in partnership with the Ministry of Agriculture. Farmers from Karaba and adjacent areas participated. The new short-duration variety was nearing

maturity and was distinctly different from the tall, late maturing local varieties grown in this area, both of which were planted in adjacent plots. Demonstrations were conducted on production, crop protection, gross margin analysis, utilisation and availability of seed. Soon after harvest, the farmer sold all of his seed crop from his 1 ha plot and realised more than KES10,000 (about US\$150), which he used to produce more seed. Very little additional support was provided by the project to the farmer. Several other farmers started producing seed for sale. Because of its good grain characteristics, farmer entrepreneurs found ready markets for their grain in local traders and major urban centres such as Nairobi, which stimulated expansion of the production area. A survey conducted by ICRISAT and the Overseas Development Institute (ODI) showed that this variety had become known to all farmers and was being grown by 68% within a period of 12 years (Jones *et al.*, 2001). Three-quarters of farmers found out about the variety through observing it growing in the field, and obtained seed primarily from other farmers. Factors favouring the diffusion of the variety included its attractiveness as a cash crop; the ease with which it could be distinguished from other varieties; the low seed rate; and the relative ease with which growers were able to maintain seed purity. Farmers expressed a willingness to pay for fresh seed, which suggests that more effort needs to be made to involve the formal seed sector. Twenty-seven years since its introduction, the variety has spread to neighbouring counties of Kirinyaga and Embu among others, without any external injection of seed or funds.

Onion seed production

Although bulb onions (*Allium cepa* L.) have been grown in Kenya for more than 70 years, farmers have always relied on imported seeds as there is no local production. Bulb onions are biennial, producing bulbs during the first season and seeds during the second season. Vernalisation is required for the transition from vegetative to reproductive phase. Optimal vernalisation temperature is about 8–10°C for 2 months. While this poses no problem in temperate climates where low temperatures can be realised during the colder winter and spring months, it is a major constraint in tropical countries such as Kenya, because ambient temperatures range between 14 and 30°C in onion-growing areas. Five new onion varieties developed at the University of Nairobi, in partnership with Hebrew University of Jerusalem and Hazera Seed Company (Israel), were formally released in 1994 by the Ministry of Agriculture (Kimani and Kariuki, 1994; Table 1).

Table 1. Maturity, bulb size, bulb skin colour and yield of new onion varieties developed at the University of Nairobi

Variety	Maturity	Bulb size	Bulb skin colour	Yield (t/ha)
New varieties				
KON 1	153–191	Large	Light brown	32
KON 4	158–198	Large	Light red	29
KON 6	154–205	Medium	Bright red	22
KON 7	154–205	Large	Yellow	34
Old varieties				
Bombay Red	160–197	Small to medium	Red/purple	16
Red Creole	150–212	Medium	Red	18
Tropicana Hybrid	162–207	Large	Red	20

Sources: Kimani and Kariuki (1994) ; Kimani *et al.* (1994)

Studies were initiated to determine the potential of onion seed production under local conditions. Initial results indicated that onion seed can be produced by artificial vernalisation by storing bulbs in cold rooms at optimal temperatures for 2 months. However, this required large capital investment and operational expenses, which would translate into expensive and unaffordable seeds. The second option was to determine if natural vernalisation could be achieved by storing bulbs at ambient temperatures at high-altitude locations. Cured bulbs of the eight new varieties and three local checks were vernalised in a cold room at 5 or 10°C; in a well ventilated grass thatched potato warehouse at Njambini Farmers Training Centre (2,350 m.a.s.l., mean temperature 13.9°C), and room temperature at Kabete Field Station (1,820 m.a.s.l., 21.4°C). After 8 weeks in storage, treated bulbs were planted at four locations – Kabete, Njambini, Kibirigwi and Marigat. Results showed that interactions between location, variety and storage temperature were highly significant for days to flowering, stalk height, umbels per plant, 1,000-seed weight and seed yield. Varietal and vernalisation temperature were significant for seed germination rates. Bulbs stored at 10°C had the highest seed yield, followed (in order) by those stored at 13.9°C and 21.4°C (Table 2), except for Bombay Red, which produced higher seed yield at 21.9°C. Bulbs stored at room temperature at Njambini flowered at all locations for the 2 years. The results showed that commercial seed yield can be obtained in the tropics by vernalising bulbs at high altitudes and producing seed at lower altitudes.

Table 2. Effect of vernalisation temperature on seed yield of onion cultivars grown at four locations in Kenya

Cultivar	Temperature (°C)	Seed yield (kg/ha)				
		Kabete	Kibirigwi	Marigat	Njambini	Mean
KON 1	5	272	235	222	214	235
	10	726	646	800	414	646
	14.4	458	421	609	382	467
	21.9	130	174	164	161	157
KON 7	5	321	236	211	209	244
	10	767	636	674	574	663
	14.4	492	523	551	485	513
	21.9	114	128	184	105	132
Tropicana	5	219	219	230	128	175
	10	516	516	364	369	422
	14.4	372	372	298	249	290
	21.9	84	84	129	104	106
Mean		343	304	282	222	288

Source: Kariuki and Kimani (1997)

Bean seed production

In June 2008, 12 new bean varieties developed by the University of Nairobi were formally released by the NVRC. Nine were bush and three were climbing bean types (Table 3). To commercialise these varieties, the university had to overcome many challenges. Available nucleus seed of each variety was limited. Farmers were demanding seeds after the local print media highlighted the qualities of the new varieties, which included multiple resistance to diseases, earliness, drought tolerance, wide adaptation, highly marketable grain types, and better grain yield than any of the existing commercial

varieties. Seed laws demanded that only certified breeder, pre-basic, basic and certified seed could be sold to farmers, because dry bean, unlike pigeon pea, is a schedule II crop. Moreover, only registered seed merchants could produce certified seed. The university did not have expansive land tracts, the personnel to produce adequate certified seed, or a national seed distribution network.

Table 3. Growth habit, market class and yield potential of new bean varieties developed at the University of Nairobi

Variety	Growth habit	Market class	Yield potential (kg/ha)*
Miezi Mbili	Bush	Speckled sugar	2,300
Kenya Early	Bush	Speckled sugar	2,150
Kenya Sugar	Bush	Speckled sugar	1,818
New Rosecoco	Bush	Red mottled	2,300
Kenya Red Kidney	Bush	Red kidney	2,800
Super Rosecoco	Bush	Red mottled	2,800
Kabete Super	Bush	Red kidney	2,470
Kenya Wonder	Bush	Red kidney	2,090
Kenya Umoja	Bush	Red mottled	2,300
Kenya Safi	Climber	Speckled sugar	3,000
Kenya Tamu	Climber	Red mottled	3,500
Mavuno	Climber	Red mottled	4,500

* Yield figures based on NPTs conducted by KEPHIS, 2005–07.

The majority (90%) of dry bean seed in Kenya has traditionally been produced and distributed mainly through informal channels since the release of the first varieties in 1984; only limited quantities were produced and marketed by the East African Seed Company and Simlaw Seeds Ltd.

To overcome these challenges, nucleus and certified breeder seed production was initiated at Kabete Field Station under the supervision of KEPHIS in 2008 and 2009. The university registered a seed company, UniSeed Ltd, through which certified breeder seed would be produced. At the same time, several seed companies expressed an interest in partnering with the Bean Research Programme in the production, promotion and marketing of seeds of the new varieties. A technology licensing agreement was negotiated with Simlaw Seeds Ltd, a subsidiary of Kenya Seed Company. In this agreement, the University of Nairobi would provide certified breeder seed of at least six varieties on a regular basis to Simlaw Seeds. It would also provide technical support during the production of pre-basic, basic and certified seed. The first consignment of certified breeders' seed produced at Kabete Field Station was handed over to Simlaw Seeds in November 2010. To produce pre-basic and basic seed, smallholders (farmers who produce seed on at least 1 acre), medium-scale farmers (>2 ha) and large-scale farmers (>5 ha) were contracted in Naromoru, Meru, Kirinyaga, Isiolo, Naivasha, Nyeri, Murang'a and Bungoma. Although common bean is highly self-pollinated (99%), it was necessary to maintain the mandatory minimum isolation distances required by the *Seeds and Plant Varieties Act* (Chap. 326). This was a major constraint, especially for smallholder farmers with small land parcels. Moreover, it was important to organise the farmers into clusters to facilitate field inspection, and to reduce technical support, collection and other operating costs. Staking climbing bean varieties was a challenge for farmers who had traditionally grown bush type bean varieties. The farmers tested various staking options including the use of sisal twine, wire trellises and stakes. Growing climbing

beans in association with maize was not acceptable to regulatory agencies. The climbing beans were too vigorous and tended to strangle the maize plants, adversely affecting their productivity.

Table 4 shows the quantities and seed categories of the new dry bean varieties produced in various locations in Kenya during the short and long rainy seasons of 2011 and 2012. More than 9,000 kg of seed was produced during the long rainy season of 2011. Of this, 315 kg was nucleus seed stage I and II produced at Kabete Field Station. Nucleus seed goes through three stages under certification before it is used to produce breeder seed. Certified breeder seed delivered to Simlaw Seeds in November 2010 was used to produce 4,500 kg of pre-basic and basic seed at Naivasha, Isiolo and Kabete field stations. This implied that various categories of seed must be produced each season and advanced to the stage in subsequent seasons. Certified seed produced increased to 21.4 t during the short rainy season of 2011. More than 80 ha of seed crops were planted each season in 2012 and 2013. Certified seed was first offered for sale to growers during the 2013 long rainy season.

Table 4. Seed of new bean varieties produced in 2011 and 2012

Season	Category of seed	Quantity (kg)
Long rainy season 2011	Nucleus	350
	Breeder	4,129
	Basic	4,562
	Total	9,041
Short rainy season 2011	Nucleus	800
	Breeder	8,000
	Basic	12,667
	Total	21,467
Season	Category of seed	Quantity (ha)
Long rainy season 2012	Nucleus	1.2
	Breeder	7
	Basic	73
	Certified	–

Although the initial certified seed production was largely carried out by the Bean Research Programme and Simlaw Seeds, a new partnership was formed in 2013 between the Seed Enterprise Management Institute (SEMI) of the University of Nairobi, Simlaw Seeds and the Bean Research Programme. In the new arrangement, SEMI would focus on the production of breeder seed; Simlaw Seeds would focus on the production of pre-basic, basic and certified seeds, and promotion and distribution of seeds through its country-wide network of retail agents; and the Bean Research Programme would focus on production of nucleus seed, variety maintenance, development of new varieties and technical support of its partners. In November 2013, a second company signed a technology licensing agreement with the University of Nairobi to produce and market new bean varieties that were not contracted to Simlaw Seeds. The companies insisted on exclusive licensing agreements.

Lessons learned, future directions and conclusions

Based on our experiences in developing improved crop cultivars and seed delivery systems for farmers in Kenya, and other countries in Eastern Africa over the past 20 years, we can offer some observations and conclusions.

- Maize and bean are the priority crops for ASAL farmers. However, these are not necessarily drought-tolerant, but may have features that make their production feasible in semi-arid regions. Thus Katumani composite is not a drought-tolerant variety *per se* but its earliness contributes to drought escape. Similarly, beans are adapted in these regions because of their short life cycles.
- Pigeon pea, green gram, sorghum, millet and tepary beans are drought-tolerant.
- Research focus to date has been on pigeon pea and beans. Less work has been done on cowpea, green gram and other drought-tolerant crops. There is growing interest in drought-tolerant maize among researchers in a collaborative programme between KARI and the International Maize and Wheat Improvement Center (CIMMYT). CIAT and its collaborators are developing drought-tolerant bean cultivars.
- The limited demand for seed of drought-tolerant crops is partly due to limited promotion and poor links to markets.
- There are four major seed systems in Kenya. All seed systems have merits and shortcomings. None is best under all conditions and for all crops. Each system has underlying technical, institutional and socio-cultural–economic–political issues that need to be taken into consideration to improve its effectiveness.
- The main components and key players in these seed systems are poorly integrated, hence ineffective; synergy is lost because of the lack of integration.
- Farmers have several coping strategies to meet their seed requirements. Their main seed sources, which include farmer-saved, local markets, extension, research, stockists and relatives, can be exploited in developing effective seed systems.
- Correct diagnosis of the causes of seed shortages is critical for appropriate interventions.
- Public universities have a key role in cultivar development and building capacities for seed research and delivery systems because of their large pool of trained (but underutilised) personnel, field and laboratory infrastructure, and recent policy change demanding their increased involvement in national development beyond their traditional teaching and research roles.
- No single institution has all the resources (human and non-human) needed to develop, promote and implement an effective seed delivery system.

Future directions

We suggest an integrated seed delivery system involving all key players and components.

The key components of an integrated seed delivery systems are variety development and release, seed multiplication, quality assurance, promotion, a distribution and marketing network, variety maintenance, provision of storage on normal and strategic reserves, and a coordination and monitoring unit. The possible actors and their roles are described in this paper.

Some functional principles for an integrated seed delivery system are to:

- identify roles and responsibilities of each partner based on the human and physical resources, skills and current legislation;
- plan, implement and receive feedback together;
- create and provide several options to beneficiaries;
- link seed systems with markets – local, national, regional and international – to provide the pulling force and motivation to increase productivity.

Conclusion

Integrated systems require commitment, effective partnerships and resources. If in place, the expected consequences are that:

- seeds of the right variety and quality, and in adequate quantity, will reach farmers faster, in time and transparently;
- few improved varieties will remain on the shelves;
- seed sales will improve;
- Kenya will have improved capacity to deal with seed stress;
- there will be enhanced crop productivity and commercialisation of research products;
- the number of food-insecure people will decrease;
- the numbers living below the poverty line will start decreasing;
- researchers and development workers will be less frustrated;
- better returns to investment in research and development will be seen.

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