Challenges and opportunities for smallholders in banana value chains

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1 Introduction

Bananas and plantains (*Musa* spp.) rank sixth on the list of staple crops in the world (FAO, 2017). With a global production of around 86 million tons per annum, about 18 million tons are exported, while the remainder is consumed domestically. Though exports, mainly comprising dessert bananas, account only for about 20% of global production, they account for about half of the value generated (about US$13 billion out of a total of US$26 billion). Cooking bananas and plantains account for the other half of the value generated and, given that they account for about 80% of global banana production, play a critical role in terms of global food security and in national and household economies.

The bulk of export bananas belongs to the Cavendish subgroup (AAA), which by the late 1950s emerged as principal dessert bananas due to their resistance to Panama disease (Fusarium wilt) after a global outbreak had wiped out the previously dominant Gros Michel subgroup (Dita et al., 2010). The varieties consumed in the producing countries, mainly cooking bananas and plantains, show a great deal of regional variation (Sharrock and Frison, 1998). True plantains (AAB), which need to be cooked before eating, are dominant not only in West Africa, but also in Central and South America. In Southeast Asia and the Americas, cooking bananas (ABB) and dessert bananas (AAB) are the most common, while cooking bananas (AAB) are popular in the Pacific. In East and Central Africa (ECA), three main banana types are grown: 1) cooking bananas, mainly East African Highland bananas (AAA), which are largely produced for home consumption with surplus sold to

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the local market; 2) beer banana cultivars (AB, ABB and AAA-EA), which are a main source of household income when processed into banana beer and sold in local markets; and 3) dessert types, mainly comprising AAA and AB types.

In ECA alone, bananas and plantains provide food and income for more than 50 million smallholder farmers, with an annual production worth US$ 4.3 billion, equivalent to about 5% of the region's gross domestic product (FAOSTAT, 2014). The consumption of bananas in ECA is the highest in the world, providing 3–22% of total daily calorie consumption estimated at 147 kcal per person (FAOSTAT, 2014). Bananas and plantains have multiple uses. As food, they can be prepared through boiling, steaming, mashing, baking, drying and pounding (FAO, 1990). The dried leaves, leaf sheaths and petioles (i.e. the stalk attaching the leaf blade to the stem) are used as ropes, cover for fermenting cassava, nesting materials for egg-laying poultry, building materials for temporary shelters, sponges and roofing material (Akinyemi et al., 2010; Kamira et al., 2015). Banana leaves are also used for wrapping, packaging, marketing and serving of food (i.e. as plates) (Kamira et al., 2015; Karamura, 1993). The fruit peels are used as feed for livestock, while the dried peels are used in soap production (Akinyemi et al., 2010; Kamira et al., 2015).

With average yields often not exceeding 30% of the crop's potential of over 60–70 tonnes ha^{-1} yr^{-1} (Van Asten et al., 2005), banana productivity is generally low in the ECA region which comprises Uganda, Tanzania, Rwanda, Burundi, Democratic Republic of Congo (DRC) and Kenya. At the global level, banana production and yields are constrained by lack of production efficiency exacerbated by pests and diseases, such as black leaf streak, banana bunchy top disease (BBTD), Xanthomonas wilt of banana (BXW), Fusarium wilt, weevils and nematodes; soil degradation; limited application of sound farming practices; lack of fertilizers and other inputs; short shelf life of the fruit; limited availability of labour; post-harvest losses and poor market access (Akankwasa et al., 2008). These challenges need to be addressed by key stakeholders in the value chain, comprising smallholder farmers, buyers, processors and traders, in collaboration with service providers from outside of the chain, such as government agencies, non-governmental organizations (NGOs) and private businesses providing technical, business and financial services. Figure 1 shows a generic value chain of banana, with ramifications to domestic and international markets.

There have been diverse research efforts focused on the key challenges facing smallholder banana growers, but limited efforts have been made to develop integrated approaches that are adapted to the livelihoods of resource-poor smallholders. Available conventional technologies for the management of biotic and abiotic constraints of banana production include cultural control practices, clean planting material, and biological or chemical control, which are often costly, labour-intensive and/or ecologically unsustainable. In addition, it is evident that no single control method will provide a sustainable solution. Use of an integrated soil fertility and pest and disease management approach has therefore been recommended. Recent research provides insights into innovative pest and disease management practices which are ecologically sustainable. These can be combined with disease-resistant planting material emerging from conventional breeding and genetic engineering, as well as evidence-based recommendations for how to reduce post-harvest losses and improve the role of smallholders in the banana value chain.

This chapter summarizes key research findings in relation to challenges facing smallholders in domestic banana value chains, identifies opportunities for smallholders and other value chain actors and service providers for addressing these, and concludes with recommendations for future research.

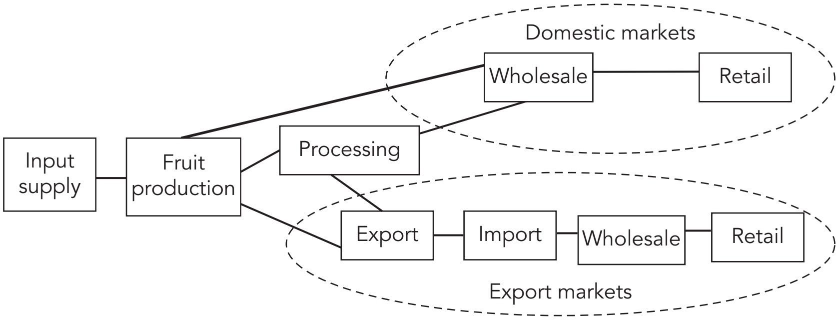

Figure 1 Generic banana value chain.

2 Challenges along the value chain

With regard to challenges in banana value chains, four phases can be distinguished: 1) pre-production, 2) production, 3) post-harvest management and 4) marketing. Table 1 provides an overview of these phases and the details are described below.

2.1 Pre-production challenges

2.1.1 Availability of labour for land preparation

Availability of labour is a key factor affecting production and yield in smallholder systems. In many of these systems, variability of labour is a principal challenge, particularly with regard

Table 1 Principal challenges along banana value chains

Pre-production	Production	Post-harvest	Marketing
• Limited availability of labour for land preparation • Limited use of and access to quality planting materials/ seeds • Social constraints • Land tenure and fragmentation	• Limited availability of labour for plantation management • Poor access to fertilizers and pesticides • Poor soil fertility and water/moisture stress • Poor crop management practices • Pests (weevils, nematodes) • Bacterial, fungal and viral diseases • Climate variability and change	• Post-harvest losses • Value adding	• Asymmetric market information • Low prices for produce/seasonal fluctuation of prices • High tax burden, especially for transport agents • Poor road networks increasing transport costs • Unequal benefit sharing among value chain actors • Low quality of the products compromising prices

to land preparation (including digging of holes for planting) which is labour-intensive and, if reliant on hired labour, costly. Labour availability is often subject to seasonal fluctuation, as there may be competing claims in view of overlapping planting and harvesting seasons of other crops (Qaim, 1999). Considering the labour-intensive nature of land preparation, households with higher number of members of economically active age are more likely to perform these tasks effectively and on time. For commercial production systems, however, land preparation is mechanized and labour requirements decrease accordingly.

2.1.2 Use of and access to quality planting material

Limited access to and use of improved seeds has been found to be a major barrier to banana production (Kikulwe et al., 2007). Farmers in a given region are predominantly reliant on suckers obtained from their own or neighbours' fields (Ocimati et al., 2013). The use of suckers significantly increases the incidence and impact of banana pests and diseases (Fujardo, 2010).

The high reliance on suckers has thus led, over time, to a build-up of pests and diseases on smallholder farms. Access to clean seeds has partly been hampered by the low investment in micropropagation facilities. Poor road networks in many parts of sub-Saharan Africa make the distribution of new seed varieties in rural areas very costly (Carruthers et al., 2009). Where local multiplication of improved seed varieties is possible, farmer networks can play an important role in addressing this challenge.

2.1.3 Social constraints

Gender

Despite their prominent role in the management of banana plantations (Table 2), women are faced with several gender-based constraints, such as lack of control over land and limited share of income derived from bananas (Ajambo et al., 2017). In many mixed households, women farmers have less power to make decisions on how to use the land and banana income and are often less involved in the marketing of bananas.

Alliances and networks

Limited interactions among value chain actors has been identified as a constraint to production, processing and marketing of bananas (Ariho et al., 2015). Alliances between value chain actors and farmer networks can help overcome bottlenecks and facilitate innovation in the value chain through provision of information, capacity development, and mechanisms for sharing benefits and risks. Information may be disseminated through formal institutions, such as public sector extension services, NGOs and mass media; or through informal mechanisms such as farmers' organizations or networks of friends, relatives and acquaintances. The different means of information dissemination have different costs and, depending on the socio-economic characteristics and location, farmers may prefer different channels and ways to receive information.

Minimum wages

The national labour laws of producing countries are often not fully implemented, and low wages discourage work in banana plantations. The working environment can be improved by increasing worker participation in decision-making regarding production, productivity and profitability within the banana subsector. Wages can be increased by targeting

Table 2 Gendered involvement in banana production in East Africa

Banana management activity	Men	Women
De-sheathing/pruning	+	+++
Weeding	+	+++
De-suckering	++	++
Corm removal	+++	+
Mulching	+	+++
Earthing up	++	++
De-budding	+	+++
Pests and disease control (trapping + other cultural practices)	+	+++
Chemical control of pests and diseases	+++	+
Soil and water conservation practices	+++	+
Digging water trenches	++	++
Selecting materials and planting	++	++
Applying manure	++	++
Applying fertilizer	+++	+
Marketing	+++	+

Note: strong (+++), some (++) and low (+).

investments that require higher levels of skill and technical expertise, upgrading wage packages and indexing the minimum wages with inflation.

2.1.4 Land tenure and fragmentation

The size of landholdings and the type of tenure system often discourage investments in banana production in Africa. Most banana crops are produced on small and fragmented landholdings in ECA. For example, the area under banana cultivation varies from 0.28 to 1 acre in Uganda (UBOS, 2010). Land fragmentation exacerbates the effects of land degradation, hampering agricultural development due to the lack of economies of scale (Niroula and Thapa, 2005). Small, fragmented landholdings also limit mechanization of farms and production at commercial scales. In the ECA region, farmers typically rely on family labour and rudimentary farm tools, rendering banana production a costly and less productive endeavour.

Land fragmentation can be attributed to a combination of local customs and legal stipulations regarding land rights and ownership. Agricultural expansion is hindered by legal restriction in relation to land tenure and cultural habits linked to the inheritance system expansion (Akinyemi et al., 2010). In Nigeria, a large portion of the land is communally owned, and private land is allocated by community members only for establishing a residence. In this system, customary rules of tenure restrict smallholders' access to communal land sufficient to feed and support their families (Arua and Okorji, 1998). This has been fostered by the high population densities and rate of population increase. For example, the population densities of Burundi and Rwanda, some of the countries dominated by smallholder banana producers are respectively, estimated at 435 and 470 people/km^2 and high growth rates between 2.3 and 3.3% per annum, which are among the highest in the world (The World Bank Group, 2016). In addition, in most African countries policies related to land fragmentation are lacking or relaxed, thus limiting banana production to a subsistence level. The underdevelopment of industrial and service sectors also means that most people in several of the banana-producing countries are employed in the agricultural sector, perpetuating land fragmentation. Investments in industrialization and the service sector coupled with appropriate policies and strategies are needed to facilitate land consolidation in a sustainable manner.

2.2 Production challenges

At the production stage, there are several challenges that affect banana production. A combination of abiotic (land, soil nutrient deficiencies and drought stress) and biotic (black leaf streak, BXW, BBTD, Foc, weevils, nematodes) stresses and lack of information, a low genetic base, social constraints and climatic change varying in relative importance in space and time, constrain production in most banana-producing regions of the world (Fermont et al., 2009; Wairegi et al., 2010). Potential yield gains from managing some of the principal biotic and abiotic constraints are summarized in Table 3.

2.2.1 Availability of labour for plantation management

Family members constitute the highest proportion of total labour involved in banana plantation management in most African farming systems (Anselm et al., 2005). In addition to planting, other labour-intensive activities include corm removal, making soil bands and trenches, de-suckering, and manure preparation and application (Table 4). As labour shortage is usually experienced during the time of land preparation and planting, households that can afford it supplement their family labour with hired labour to meet labour requirements.

2.2.2 Access to fertilisers and pesticides

Growth in agricultural productivity, for example, in ECA, has been dependent on own farm inputs (mainly manure and crop residues), a method that only helps recycle nutrients within the farming system, and does not add to the stock of nutrients in the system. Improving banana and plantain yields thus requires external chemical inputs such as mulch, fertilizers, pesticides and herbicides (Fig. 2). As most banana-growing countries in Africa are net importers of these goods, production costs are high. However, though

Table 3 Estimated yield gain due to management of priority banana production constraints in ECA

Constraint	Yield gain (%)	Source
Black leaf streak (Black Sigatoka)	30–50	Tushemereirwe et al. (2004a)
Xanthomonas wilt of banana (BXW)	80–100	Kubiriba et al. (2014)
Banana weevil	60	Okech et al. (2004)
Nutrient deficiency (K and N)	28–68	Nyombi et al. (2010)
Drought stress	20–65	Van Asten et al. (2011)

Table 4 Ranking of labour intensity of various banana management practices

Banana management activity	Labour intensity	Rank of all activities: 9 = least labour-intensive; 1 = most labour-intensive
Planting	5	1
Corm removal and splitting stems	5	2
Making soil bands and making trenches	5	3
De-suckering	5	4
Making compost manure	3	5
Weeding	2	6
De-sheathing	2	7
Applying manure/fertilizer	2	8
Pests and disease control	1	9

the use of pesticides and other chemical inputs can increase yields more effectively than non-chemical alternatives, they can also cause negative environmental and health effects (Viljoen, 2010). Given the high cost, negative effects and unavailability of fertilizers/pesticides, manure and mulch use remain the only viable alternatives and hence agro-ecological strategies for ensuring their continuous supply to farmers need to be explored/fine-tuned, promoted and integrated into the extension packages.

There are studies suggesting that the use of inputs like pesticides, fertilizers, manure and mulch is substantially low especially in African banana cropping systems (Nyombi, 2013). The input use must be emphasized to improve banana productivity and realize more profits from banana production. Future research should promote investment in developing agribusinesses aimed at establishing links with banks and microfinance institutions to provide credit and loans to farmers to purchase high-quality seeds, fertilizer and other necessary inputs. Access to credit can also help farmers establish (low-cost) community-based mother gardens and micropropagation chambers to increase access to clean and relatively cheap planting materials.

2.2.3 Soil fertility and water/moisture stress

Soil nutrient deficiencies, poor/inefficient nutrient cycling and retention of adequate soil moisture have been identified as major obstacles to enhancing banana production (Van Asten et al., 2011). Sustainable increase in banana productivity should go hand in hand with meeting the crop nutrient requirements. However, the profitability of mineral fertilizer application reduces with increasing distance from the main markets (Wairegi et al., 2010). This calls for combined use of mineral and organic nutrient sources and soil water conservation measures for improving nutrient use efficiency since most banana production zones are distant from the markets. The interactions suggest that there are trade-offs to be optimized and synergies to be harnessed for management of these constraints. We postulate that poorly managed plant stands may affect the ability of the cropping systems to sustain their nutrient stocks. Banana is a shallow-rooted crop with high nitrogen and potassium requirements. Potassium and nitrogen are highly leachable nutrients and,

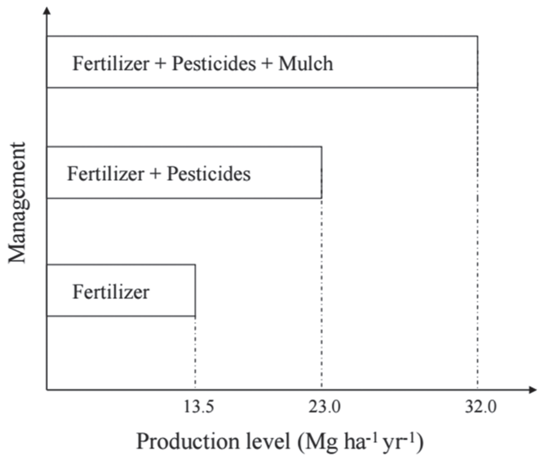

Figure 2 Response of East African Highland bananas to management options in Masaka, central Uganda. Source: Rubaihayo et al. (1994).

among cations, potassium is the most dependent on standing biomass to maintain its levels in the cropping system. Poor biomass can lower potassium stocks, which in turn exacerbates nutrient leaching to depths inaccessible to the banana plant/mat. Similarly, banana thrives under a thick organic mat/mulch layer.

Though the evidence is less clear, it is believed that high banana weevil and nematode pest status reflects poor management, declining soil fertility and the presence of already stressed plants. Poorly nourished banana plants may be less capable of defending themselves against (i.e. more susceptible to) weevil and nematode attack. Stressed plants are also subject to the high mat phenomenon, by which the corm comes out of the ground, increasing the plant's vulnerability to weevil attack (Gold et al., 2001).

2.2.4 Crop management practices

Small-scale banana producers often adhere to traditional practices of producing banana in their backyard or where it incidentally grows, generally without access to improved cultivars. Most of the recommended crop management practices are knowledge-intensive, labour-intensive and costly to apply and often poorly adopted by small-scale farmers (Ochola et al., 2013). Knowledge extension to farmers coupled with adaptation of technologies to local conditions is crucial for banana cultivation. This has, however, been hampered by poor and, in some instances, non-existent extension structures and/or services.

2.2.5 Pests (weevils and nematodes)

The banana weevil *Cosmopolites sordidus* (Germar) (Coleoptera: Curculionidae) and a complex of root parasitic nematodes (*Radopholus similis*, *Pratylenchus goodeyi* and *Helicotylenchus multicinctus*) are the major pests of bananas. They destroy roots and parts of the rhizome, thus reducing anchorage and interfering with water and nutrient uptake. These pests are most damaging at altitudes of <1500 m, can cause yield losses >50% and can reduce the effect of investmenting in soil fertility and water management (Gold et al., 2001). The weevil is a hydrophobic, soil-borne pest and therefore soil management (e.g. factors affecting soil moisture) may influence the pest's population densities, behaviour and damage levels. Both the weevil and nematodes are disseminated through the movement of infested planting material.

Research findings suggest that no single control strategy will provide complete control of banana pests. Therefore, a well-defined integrated pest management (IPM) approach might offer the best chance for successful pest control. For small-scale producers, the components of such a programme include cultural (e.g. residue management), botanical (use of neem and concoctions/plant extracts), conventional and non-conventional genetic improvement (host plant resistance) and (in some cases) chemical control. Several of these IPM components are being used by farmers in Uganda although lack of labour remains the main constraint on the use of these practices (Bagamba et al., 2007).

2.2.6 Bacterial, fungal and viral diseases

Both smallholder and large commercial banana production systems are limited by a range of diseases caused by fungi, viruses and bacteria. The fungal diseases include black leaf streak (commonly known as black Sigatoka, is a leaf spot disease caused by the fungus *Mycosphaerella fijiensis*), Fusarium wilt caused by *Fusarium oxysporum cubense (Foc)*, BBTD caused by the banana bunchy top virus (BBTV) and banana streak caused by the *banana streak virus*, while the bacterial diseases include BXW caused by *Xanthomonas campestris* pv. *musacearum* and Moko/Bugtok and blood disease caused by *Ralstonia solanacearum* and the blood disease bacterium (*Ralstonia syzygii subsp. celebesensis*), respectively (Blomme et al., 2017).

The disease challenges are to a large extent caused by the fact that bananas are vegetatively propagated so that pathogens can move around in infected planting material. In addition, few acceptable resistant cultivars have been developed through conventional breeding due to the near sterility of commonly grown/accepted cultivars. Research centres are very active in developing methods for the control of banana diseases. Some of these efforts include the development of resistance towards Fusarium wilt, BXW and BBTD through genetic modification, development of diagnostics to support the dissemination of disease-free banana planting material and cultural control options.

Fusarium wilt

Fusarium wilt is a destructive disease and a big threat to the global banana production. It is a soil-borne fungus caused by *Fusarium oxysporum* fsp *cubense* (Foc). It infects bananas through their roots and moves relatively slowly in the soil, though can be moved over long distances through infected planting material, irrigation and runoff water and in soil attached to machinery or footwear (Stover, 1962). Importantly, it can remain in soil (as ascospores) for decades even in the absence of bananas (Ploetz, 2015). Foc has several races, with each race infecting different cultivar groups. The most important races are Race 1 and (Tropical) Race 4 (TR4). Race 1 is ubiquitous in banana-growing regions and has historically had a major impact on commercial banana production. This fungus was the reason why the major multinational banana-producing companies changed from susceptible 'Gros Michel' to resistant 'Cavendish' cultivars. Both Cavendish and East African highland bananas are resistant to Foc Race 1 but 'Lady finger' in Australia and 'Sukali Ndizi' in Uganda are susceptible as are many other cultivars (Tushemereirwe et al., 2004a). Foc TR4 is very different. Previously limited to Darwin in Australia and Southeast Asia (Ploetz, 2006), it has recently been reported to be also present in Oman, Pakistan, Lebanon, Jordan and Mozambique (Ordonez et al., 2015). Compared with Foc TR1, Foc TR4 is a much more serious threat as it infects a wider range of cultivars including Cavendish. There are currently no validated methods available for effective control of Foc TR4 other than taking advantage of cultivar resistance and using genetic modification (including somaclonal selection) as a promising way for generating resistant bananas (Krishna et al., 2016).

Black leaf streak disease (commonly known as black Sigatoka)

Black leaf streak disease (commonly known as black Sigatoka) is a leaf spot disease of banana and plantain caused by the ascomycete fungus *Mycosphaerella fijiensis* (Morelet). The disease causes necrotic lesions on the leaves of many Musa cultivars, reducing their photosynthetic ability, prematurely ripening the fruit and leading to yield reductions of 30–50%, in some cases as high as 80% (Mobambo et al., 1993).

Control of black Sigatoka in commercial systems is mostly reliant on frequent (weekly) fungicide application (de Bellaire et al., 2010). Such frequent application of fungicides is costly and out of reach of small-scale farmers. Frequent fungicide application also has socio-economic implications that include human health and environmental hazards (Ploetz, 2001). Small-scale farmers, for example, in ECA prune old leaves to minimize infections in the younger leaves. Pruning also allows in solar radiation that reduces the survival and development of the fungal spores (Amponsah et al., 2010).

Banana bunch top disease

BBTD is regarded as the most serious viral disease of banana, causing significant yield losses. The disease is present in most of the banana-growing areas of Asia with notable exceptions of Thailand and Malaysia; in Central Africa (Burundi and DRC) and Zambia, Angola and Malawi in Southern Africa and Hawaii in the Americas (Kumar et al., 2011). The disease is caused by the BBTV, a circular ssDNA virus belonging to the genus *Babuvirus* in the family Nanoviridae. The virus is transmitted from plant to plant by the aphid *Pentalonia nigronervosa* that are widespread in Africa (Adegbolo et al., 2013) and through infected planting materials. Plants infected at early growth stages are severely dwarfed and do not bear fruit. Currently, management of BBTD is reliant on cultural practices such as timely rogueing of infected plants, killing *in situ* with herbicides the infected plants and use of clean planting materials. Methods for diagnosis are still poor in some of the affected regions, especially in sub-Saharan Africa. There are no known resistant cultivars. As such, breeding for transgenic virus resistance is now considered the most appropriate strategy for long-term BBTD control.

Banana Xanthomonas wilt (BXW) and Moko/Bugtok disease

Bacterial wilts that have become a major threat to banana production include banana Xanthomonas wilt, Moko/Bugtok and blood disease. The Xanthomonas wilt disease was first observed on enset in Ethiopia in the 1930s (Castellani, 1939) and was identified as Xanthomonas wilt in 1968 on enset (Yirgou and Bradbury, 1968). Its infection causes losses in banana production through early fruit ripening and rotting of fruits, and through leaf yellowing and wilting, and eventual death of plants. The disease was reported to be found in both Uganda and east DR Congo in 2001 and has now spread to all countries in ECA (Smith et al., 2008; Tushemereirwe et al., 2003, 2004b; Blomme et al., 2014). To date, although all types of bananas in the ECA have been found susceptible, the ABB beer banana cultivars that are susceptible to insect-mediated infections probably play a critical role in facilitating the spread of the disease (Tripathi and Tripathi, 2009).

The Moko disease is found in Latin America, the Caribbean and Southeast Asia (Buddenhagen, 1994). The wilt caused by the banana blood disease pathogen is affecting dessert bananas and local cooking banana cultivars in Indonesia and New Guinea (Eden-Green, 1994; Davis et al., 2001). All the bacterial wilts lead to plant leaf yellowing, dry rot of the flower, browning of the fruit pulp and appearance of bacterial ooze in cut plant tissues (mainly pseudostem and leaves) (Blomme et al., 2017), resulting in production collapse.

Transmission of these bacterial diseases occurs mainly through insect vectors (e.g. stingless bees) and the use of contaminated farm tools and infected seedlings. Spread of the *Ralstonia* spp. also occurs through soil, irrigation and runoff water. Management practices employed for the control of bacterial wilts include the elimination of infected plants, use of disease-free planting materials, disinfection of cutting instruments/tools with 5% chlorine or 90% ethanol, early removal of male flower buds and strict quarantine (Blomme et al., 2014).

2.2.7 Climate variability and change

Climate variability and change is another factor affecting banana production worldwide. In addition to the typical variation of temperature and precipitation regimes, there is an increasing need for farmers to address the effects of climate change. According to climate models, by 2070 the land area suitable for bananas will increase globally by 50% due to more favourable temperature and rainfall patterns in the subtropics and tropical highlands (German Calberto et al., 2015). At the same time, higher temperatures will raise water demand, which is projected to increase by 12–15% (Washington and Pearce, 2012). Higher temperatures also favour the spread and impact of pests and diseases. Colder dry seasons, on the other hand, will increase the time for ripening.

The impact of climate change on temperature and rainfall in any specific location is reasonably uncertain; thus policies will need to be flexible and adaptable, so as not to overly rely on a given strategy. By examining detailed maps of productivity trends in the light of climate change, it is possible to identify climate risk areas (areas with projected losses) and climate opportunity areas (those with future gains). Researchers will need to work together with farmers to develop new crop varieties along with supporting agronomic and husbandry methods, extension services and mechanisms for scaling up and out, for successful agricultural adaptation to climate change. Moreover, the more than 500 banana/plantain varieties around the world (German Calberto et al., 2015) present a key resource for climate change adaptation that needs to be further explored and used to improve yield. Adjusting agricultural practices for varieties grown in given areas can help maintain or increase production levels. Investment in breeding for climate-resilient banana cultivars should be considered a priority in research efforts. There is a need to initiate work with local farmers to promote education on pest and disease control as well as best practices for water-saving irrigation techniques.

2.3 Processing challenges

2.3.1 Post-harvest losses

Post-harvest losses are a major challenge in the value chains of cooking bananas and plantains. Generally, the primary factors causing post-harvest losses in fresh produce are of mechanical, physiological, pathological or environmental nature (Kader and Rolle, 2004).

Losses are incurred by secondary factors resulting mainly from inadequate technology applications and quality control. In Africa, high post-harvest losses caused by inadequate post-harvest handling are one of the major factors limiting the expansion of banana production (Olorunda, 2000). Similarly, lack of adequate infrastructure for pre-packaging, cold storage, packaging and distribution, post-harvest treatments and washing, along with production constraints, are reported to cause low productivity and post-harvest losses in most banana-producing countries in ECA (Gabre-Mariam, 1999). Considerable volumes of cooking bananas and plantains are damaged, or lost altogether, before reaching the target markets (Gabre-Mariam, 1999).

As a perishable crop, banana requires proper mechanisms for storage. A key limitation is the lack of infrastructure and technologies to store bananas, so as to use them during times of scarcity. In Uganda, for example, bananas are in high supply during the peak season in June and July, increasing the risk of waste and losses. In addition, traders offer low prices in times of oversupply, while farmers have few alternatives to immediate selling. In contrast, prices soar during periods of low production, particularly in the months of November and December, when only few farmers have bananas to sell. Recent studies in Uganda indicate that during low production (scarcity), on-farm post-harvest losses affect about 3.3% of the produced volume (physical losses) and 5.4% of the generated value (economic losses), increasing during the peak period to 9.6% and 8.1%, respectively (Kikulwe et al., 2017). Overall, post-harvest losses in the cooking banana value chain amount to 12%. Most losses are reported along the downstream segments of the value chain (Hailu et al., 2013). In general, economic losses often outweigh physical losses in banana value chains.

In the upstream segments of the value chain, particularly at farm level, post-harvest losses are often associated with theft (physical losses) and selling of immature bananas (economic losses). At the retail level, physical losses are also due to theft, while economic losses are due to bruising, finger-plucking and ripening. In addition, release of ethylene during bulk storage makes the fruits ripen faster and increases the risk of rotting before reaching their destination. Poor handling during ripening and transport can significantly reduce green life and shelf life which is 5–10 days after harvest. Strategies such as appropriate transportation and proper storage for limiting post-harvest losses are not readily available and, where they are, access might not be equitable in terms of gender and other factors of social differentiation (Hailu et al., 2013). Largely lacking are gender- and, overall, client-differentiated solutions for improved storage, transport and handling of bananas from the farm to the market.

2.3.2 Value adding

As a multi-use crop, banana holds the potential of significant value adding through product differentiation and processing into diverse food and other products. This potential is often only partially realized due to poor technology, low investments in agro-processing, lack of business and technical skills and weak orientation towards the needs of diverse consumer groups. Thus, bananas are often sold as fresh produce, in local markets, and with little differentiation. In addition, there is a massive underutilization of banana residuals which could serve as a raw material for value-added products, increasing agricultural productivity and reducing waste (Mohammadi, 2006). Opportunities exist for industrial use of diverse banana by-products, such as peels, leaves, pseudostem, stalk and inflorescence. This can lead to various food and non-food applications, including use as thickening agent, colouring and flavour agent; and as alternative sources of macro and micronutrients, nutraceuticals, livestock feed, natural fibres and sources of natural bioactive compounds and bio-fertilizers (Padam et al., 2014). In addition, local processing into vinegar, juice, beer and other beverages is a form of value addition particularly suitable to women, either as individual entrepreneurs or organized into collective enterprises.

Further options include processing of bananas into various products like biscuits, sweets, crisps, cakes, jam, sauce and yoghurt that are more palatable (Adeniji et al., 2010; Akinyemi et al., 2010), and blending banana fruits and foliage into livestock feeds, especially in Africa and Central America where other resources are limited. However, some challenges need to be addressed to realize their potential for value addition, particularly as regards improvements of local infrastructure, transport, retail outlets, processing facilities and associated investments. This requires joint efforts by public and private sectors, including co-investments, credit lines and tax breaks. An enhanced enabling environment would also encompass public purchasing policies (e.g. banana products as part of school meals) and other policies that promote the production, processing and consumption of different banana products.

2.4 Marketing challenges

With a global value of international and national trade exceeding US$25 billion a year, banana markets constitute one of the principal commodity markets and provide employment and income to more than 50 million people worldwide. While export markets are largely controlled by a few multinational companies and major retailers in the importing countries, domestic markets involve a broad array of stakeholders including smallholders, transport agents, processors, petty traders and other retailers. Domestic markets for cooking bananas and plantains, in turn, are found across a broad spectrum of small- and medium-size towns in rural and peri-urban areas as well as larger urban agglomerations and cities. While these markets increase opportunities for farmers and other value chain actors to generate income, they also face several challenges, such as poor transportation which increases transport costs, limited infrastructure for storage and marketing, lack of incentives for quality banana and product differentiation and scant access to credit (Mulualem et al., 2015).

One of smallholders' major impediments to commercial banana farming is limited access to reliable transport networks and viable markets (Zenebe et al., 2015). In addition to poor handling causing bruising and delays in transport due to poor roads and deficient transportation means, quality and price are compromised due to inadequate infrastructure for storing and marketing bananas in rural, peri-urban and urban market places. Limited flow of information from the markets to the farms and vice versa increases the likelihood of unnecessary shortages or peaks of supply, with price fluctuation affecting both farmers and consumers. During peak periods of production, supply may outweigh demand, leaving little incentive for farmers to market their produce in view of low prices. Fluctuation of prices is often aggravated by limited availability of technologies for processing and other forms for increasing shelf life. Income is further compromised by lack of product differentiation in terms of processing and quality grading. Smallholder farmers and processors lack guidance on quality standards and incentives for meeting them. Bananas are usually trucked to markets without specific protection, resulting in unnecessarily high losses through physical damage and quality deterioration. Many smallholder farmers are unorganized and rely on middlemen who pick up their produce at the farm gate.

Transactions are often based on asymmetric market information and rarely involve formal contractual commitments. Opportunities for processing banana, for example into juice, are hampered by limited information on markets for substitutes (juice from other fruits), and associated requirements in terms of quality and hygiene. Organizing into collective enterprises, such as cooperatives and farmers' associations, with a clear business model would allow smallholders to bulk production, increase their bargaining power, engage in processing and, overall, realize economies of scale. Still, close collaboration with value chain actors near the final markets is required to tap into their knowledge on consumer segmentation, capacity and willingness to pay for differentiated banana products, and price differentials across products and markets.

Cost competitiveness for marketing cooking bananas and plantains in international markets is severely limited in view of high domestic transportation costs, taxes for transport agents and shipping rates for sea freight, along with the need for a cold chain (cooled containers for fresh products) and relatively limited demand in importing countries as compared with that for dessert bananas. In domestic markets, the marketing of ripening varieties is more challenging than that of cooking varieties as post-harvest losses tend to increase during ripening. Such challenges compromise value chain efficiency and, hence, incomes of both traders and farmers. Post-harvest deficiencies compromising marketability are linked to bananas developing unacceptable qualities in terms of colour and texture due to overripening, inappropriate post-harvest handling and limitations in market infrastructure and organization. There is also a lack of grading and standard weight measurement, resulting in erratic price setting, affecting both farmers and consumers.

Addressing these challenges requires improving the information flows among value chain actors, also to reduce the likelihood of intermediaries taking advantage of poor rural producers who often lack market information (Ariho et al., 2015). Asymmetric market information is a general problem in most tropical countries where formal market information services like radio broadcasts are absent or lack local specificity. This is a clear intervention point for national and local governments. NGOs specialized in value chain development can also contribute to promote forward and backward linkages in the value chain that enable value chain actors to embrace market dynamism and improve their understanding of consumer preferences. In addition, stronger linkages with external service providers, such as input firms and business advisory services, can improve the efficiency of value chains, as do modern information and communication technologies. In Uganda, for example, banana traders use mobile phones to carry out transactions with producers in rural areas and buyers in urban markets (Kikulwe et al., 2014). Similarly, the use of mobile money systems allows banana-growing households to purchase significantly higher amounts of inputs – fertilizers, pesticides and hired labour – and to sell a larger proportion of their harvest in the market (ibid.). Such technologies help overcome cash limitations and enable transactions with buyers from outside their local communities (Sekabira and Qaim, 2017).

Looking forward, R&D efforts need to identify effective and efficient ways for improving information flows in the value chains, extending the shelf life of bananas, differentiating products in line with established, location-specific demand and broadening opportunities for processing and marketing of by-products. On the demand side, growing urban populations and middle-class, along with expanding supermarkets and other retail outlets, will provide quality and price signals to the farmers. The latter, in turn, could become organized into cooperatives and other forms of collective enterprises to strengthen their position in the value chain, enhance their advocacy vis-à-vis local and national governments and improve their access to credit. For example, farmer organizations such as High-ridge Banana Growers and Marketing Association in Kenya and Nakasongola District Farmers Association in Uganda provide various benefits to their members, including access to value-adding technologies, technical assistance and training, collective marketing, access to farming inputs and credit and women empowerment (Nyang et al., 2010). Complementary training may be provided by government agencies and NGOs, particularly as regards organizational and management training, timely production to meet market demand/periods of peak prices, maintaining product quality throughout the value chain and obtaining up-to-date market information, as well as basic business practices like recordkeeping and effective marketing. Finally, improvements in the marketing and general infrastructure requires state-borne investments in the road network and other basic infrastructure, while the private sector can be expected to provide co-funding for infrastructural improvements that directly enhance value chain efficiency (e.g. cold chain investments).

3 Enabling an environment for addressing the challenges

Enabling environment for banana production, processing and marketing is invariably linked to a wide range of public policies and institutions, but also relates to private institutional arrangements, such as voluntary sustainability standards and the provision of technical, business and financial services by NGOs and private firms. In this sense, the enabling environment for value chains of cooking bananas and plantains also includes access to input markets, market information and crop production technologies to ensure productive, environmentally sound production oriented towards the demand of diverse consumers and, overall, positive implications for agricultural development and food security.

In a more classical sense, access to critical production factors such as land, labour and capital is a critical element of the enabling environment (Ariho et al, 2016). Improving access of smallholders to land, particularly women, is featuring prominently on the agendas of NGOs and advocacy organizations and, increasingly, also on those of political decision-makers. In Uganda, for example, the National Land Policy has recently been adjusted such that historical injustices are redressed to protect or improve the land rights of communities and women and, thus, their participation in banana production. Such legal adaptations are critical as lacking access to land is a major constraint on women's stronger participation in banana production as in the absence of land titles their access to credit is thwarted. In Uganda, women barely own 20% of land and yet they contribute over 65% of labour to the production, processing and marketing of bananas (Republic of Uganda, 2013). In addition to agricultural production, women play a key role in household reproductive activities. Efforts to improve productivity in banana and other crops therefore need to address gendered division of labour in smallholder households and the differentiated access of women and men to productive assets including land, machinery and equipment and other farming inputs.

Access to quality planting material is also a critical aspect of production. However, more than 90% of the planting material originates from informal exchange among neighbours, purchases in the local market and use of own materials (Otieno et al., 2016). This increases the vulnerability of banana plantations to diseases and pests. Provision of quality materials is dependent upon investments in local tissue culture laboratories and decentralization of governmental pest and disease control agencies. Such seed inspection units need to be equipped with more seed inspectors to reach out to broad numbers of farmers and sensitize them on the use of clean planting materials.

Addressing post-harvest constraints related to processing and marketing requires stronger engagement by both value chain actors and public sector entities for joint investments and action. As banana is a perishable crop, its processing and marketing are dependent on adequate infrastructure to facilitate transportation, storage and marketing. Improvements in the road network and warehouses are critical for reducing post-harvest losses, lowering transaction costs and overall marketing of bananas (Ariho et al., 2016). Private sector engagement in agro-processing and co-funding of infrastructure can be fostered through tax breaks, low-cost credit and other institutional incentives.

Linkages between the providers of technical, business and financial services can be strengthened by bringing them together with producers, processors and traders in business roundtables and encouraging complementary service offer. This can be paired with promoting cooperatives and other forms of collective enterprises as vehicles for farmers to access inputs and services and, overall, strengthening their role in the value chain. In Uganda, for example, the National Agricultural Advisory Services (NAADS) Act of 2001 provided the government extension institution with the mandate to support farmers by establishing functional organizations (structured and operational institutions) to ensure collective procurement and marketing, and collective access to financial services. The NAADS act was further mandated to aid farmers in creating options for financing and facilitating the participation of the private sector in funding agriculture and engaging in agro-processing (Republic of Uganda, 2001). However, the act was trimmed down in 2015 and has been replaced by a wealth creation programme led by the military who are unprepared to provide agricultural extension services, leading to a gap in extension and much needed farmer support.

Successful value addition and agro-processing not only require injection of financial capital, but also investment in human capital to develop productive and commercial means and skills of value chain actors including smallholders (Ariho et al., 2016; Spilsbury et al., 2004). Where extension services are absent or not up to their task, NGOs and private sectors need to provide the required services. These services need to be informed by solution-oriented research addressing the wide range of production, processing and marketing challenges indicated above. This, in turn, requires collaboration between national research institutions and universities and international research organizations.

Finally, strengthening the enabling environment for cross-border trade of cooking bananas and plantains in regional markets is a way forward. For example, there is great potential for fresh or value-added banana products in the East African Community (EAC), specifically in Kenya and Sudan (EAC, 2014). Recent advances in EAC integration, including the development of a customs union, have eliminated tariffs and reduced transaction costs related to customs, particularly clearing of goods and other administrative services. The EAC has also been working towards developing the East African industrialization policy and related strategies to create an integrated framework for industrialization through agro-processing and increased trade in value-added products among the EAC countries (EAC, 2014). It is expected that this will lead to growth of cottage industries and stimulate agro-processing and value addition for major crops in East Africa.

4 Future trends

With yields varying from as low as 5 t/ha on farmer's fields to as high as 70 t/ha on research stations (Fermont et al., 2009; Van Asten et al., 2005), yield gaps facing smallholder farmers are excessively high. As a result, research and development efforts focus on effective and efficient ways for increasing banana production and resulting food security and income through improvements at production, processing and marketing, levels for the benefit of smallholders and other resource-poor value chain actors. Table 5 provides an overview of key research areas, associated opportunities for increased production, processing and marketing, and suggestions for complementing current endeavours through additional efforts in the future.

Challenges associated with banana cultivation may primarily be solved through sustainable intensification of production, calling for urgent development and deployment of new validated technologies (Bagamba et al., 2007; Edmeades et al., 2007). Research with a focus on key biotic and abiotic constraints has well advanced as regards EAHB cropping systems. For example, norms for assessing nutrient imbalances applicable to EAHB using compositional nutrient deficiency diagnosis have been developed, as part of integrated systems and associated recommendations (Wairegi et al., 2010). A model for quantitative evaluation of fertility in tropical soils has been calibrated for EAHB (Nyombi et al., 2010) to quantify nutrient requirements for defined yield targets. A dynamic crop growth model – LINTUL-BANANA2 for water-constrained production – has been developed to quantify water requirements (Taulya, 2015). A range of pest management technologies already exists (see Masanza, 2003; Tinzaara et al., 2007). Significant progress has also been made for managing the expanding threat of banana diseases, such as BXW (Blomme et al., 2014; Smith et al., 2008; Tinzaara et al., 2016; Tripathi and Tripathi, 2009) Black Sigatoka (Tushemereirwe et al., 2004a), Foc TR1 and TR4 (Dita et al., 2013) and BBTD (Kumar et al., 2011, 2015).

Future research efforts should seek to unravel the interactions between abiotic and biotic constraints and to evaluate trade-offs and synergies between management options, with the aim of designing client-specific control packages for different types of smallholder farmers. The knowledge generated on biotic and abiotic interactions will be incorporated into a growth model for simulating EAHB production. This model, in turn, will inform the development of an aggregate bio-economic model for *ex ante* analysis of integrated soil fertility and pest management and good agricultural practices. Findings need to be translated into gender-differentiated capacity development initiatives to ensure adequate fit and utilization of the new technologies. Outreach to smallholders will be facilitated through the promotion of farmer cooperatives and associations as a vehicle for integrated approaches with a multiplier effect that focus on cultural practices, post-harvest losses, value adding, market orientation, leadership skills of women and savings and credit facilities (Bihurwa et al., 2012).

Socially and environmentally sustainable intensification of banana production is also urgently needed to boost productivity for supplying growing populations. Recent research findings on key biotic and abiotic constraints in East African highland bananas (Nyombi et al., 2013) could be applied to sensitize smallholders as regards banana seed systems and appropriate technologies for managing soil, water and pests and diseases. There is also a need for appropriate gender-responsive decision support tools that can help promote intensification of cropping systems in banana-growing areas in line with the diverse realties and needs of male- and female-headed and mixed households. Strategies need to be developed that promote: i) access to clean planting material and ii) location- and

Table 5 Key research areas and opportunities for increasing banana production along the value chain

Key areas of research	Opportunities for increased production, processing and marketing	Current R&D efforts	Future R&D efforts
Pre-production • Labour • Land • Socio-institutional constraints • Planting material	Inputs for enhancing production are available in the markets (e.g. various highly productive genotypes/cultivars, organic and inorganic fertilizer formulations suitable for banana)	Understanding of banana seed systems and promotion of a smallholder-friendly seed system Increase knowledge on banana cultivar performance according to various agro-ecological zones	Explore strategies for land consolidation and mechanisation Explore strategies for improving farmers' access to inputs
Production • Labour • Soil and water • Pests and diseases • Inputs • Drought risks	Management technologies/ IPM package(s) available for key pests and most diseases Set of agronomic practices to boost production available	A model for quantifying nutrient requirements for defined yield targets Sustainable management of Xanthomonas wilt, *Fusarium* spp. and banana bunchy top disease that are key constraints to banana production	Development of gender-differentiated strategies for improved production, processing and marketing of banana Need to understand bottlenecks to adoption and rightful application of technologies Promote education on best practices for water-saving irrigation techniques Exploration of appropriate strategies for bridging the gap between research and extension
	Extensive studies on Musa germplasm diversity conducted, germplasm conserved *in situ* and *ex situ* in different collections (national and international) These materials also support breeding efforts Conventionally bred black Sigatoka-resistant plants. BXW-resistant genetically modified banana	Modelling BXW epidemiology Developing climate-smart, pest and disease-resistant banana germplasm by conventional breeding Mainstreaming of gender to boast production, incomes and nutrition in banana-based systems Developing and tailoring of bio-economic models for banana-based households/farming systems	Development of a banana growth model increase farmer awareness and utilization of appropriate technologies Understanding of weevil and nematode resistance mechanisms and genes that control these mechanisms Promoting GM bananas (commercializing and consumer acceptance)

Key areas of research	Opportunities for increased production, processing and marketing	Current R&D efforts	Future R&D efforts
Value adding • Shelf life • Handling • Storage • Transportation • Value addition • Product quality	Development of diversified banana products and by-products Different banana products and by-products Novel transport, storage and processing techniques	Understanding the causes of post-harvest losses and ways for reducing them Optimization of the banana handling and ripening process	Developing new differentiated products based on different banana varieties and banana by-products Capacity development for farmers to form, cooperatives and other types of enterprises
Marketing • Price levels and fluctuation • Tax regimes • Marketing infrastructure	Stimulation of demand for diversified banana products and by-products Improvements in tax regimes and facilities for transportation, storage and marketing	Banana value chain analysis	Market research to guide investment decisions and marketing strategies Policy research focusing on the enabling environment for production, processing and marketing of banana

client-specific agro-ecological intensification technologies, including options for locally adapted pest and disease control.

The development of resistant plants is a long-term strategy for pest and disease management, especially on small-scale farms, as the inclusion of such plants can be part of an integrated pest and disease management strategy. Genetic engineering is considered as one of the eco-friendly and safer methods to control banana pests/diseases and will continue to play a key role in the sustainable production of cooking bananas and plantains in Africa. This has recently been recognized by several African governments and international donors, reflected in higher financial support for research into banana and plantain biotechnology. The current efforts of national and international research centres to develop pest and disease-resistant varieties through conventional breeding based on careful selection of parents – particularly improved diploids with resistance – should continue to complement the biotechnology efforts. Such a strategy will increase the chances of developing, for example, resistance against the banana weevil. The development of rapid screening methods for testing weevil resistance in the field and laboratory is an essential step in developing resistant hybrids. A better understanding of resistance mechanisms and genes that control these mechanisms should form the focus of research priorities in developing successful resistance for the banana weevil and nematodes. Future research, therefore, should focus on long-term performance of genetically modified (GM) bananas under African field conditions, including the long-term response of weevils and effects to their natural predators. The major issues concerning GM banana plants that will need to be addressed before engaging on a broader scale in such an endeavour are their commercialization, affordability and consumer acceptance .

Limited findings are available on causes and control of post-harvest losses of ripening varieties, especially those due to diseases; ethylene physiology and ripe-fruit quality temperature management during handling; and modified-atmosphere storage and physiology. Research could help to optimize the ripening process and to reduce post-harvest losses. Further efforts are also needed to develop new products based on different banana varieties and banana by-products. Organoleptic properties, nutrient content and texture vary widely across varieties – an often-underexplored potential for new products. Similarly, peels, leaves, pseudostems, stalks and inflorescences are valuable raw materials that can be processed into diverse food, feed and other applications. Findings from such research need to be built into capacity development programmes for farmers, cooperatives and other types of enterprises which, in turn, requires the upgrading of the capacities of technical service providers who are usually specialized in production-focused topics. In addition, market research can guide investment decisions and inform the development of marketing strategies, based on consumer segmentation, analysis of capacity/willingness to pay and other critical success factors for linking supply and demand. Research findings can inform the programmes of business service providers who, in close collaboration with technical service providers, seek to strengthen the capacities of smallholder farmers, cooperatives and other forms of enterprises.

5 Conclusion

Production and trade in bananas, comprising dessert and cooking bananas and plantains, are a pillar of global food security, providing about 400 million people worldwide with access to a staple food and more than 50 million people with a critical source of cash income. However, the stages pre-production, production, post-harvest management and marketing of banana face several challenges. At the pre-production stage, principal challenges relate to land, inputs and planting materials. At the production stage, appropriate technologies are needed for improving soil fertility, managing pests and diseases and optimizing water use. Post-harvest challenges are associated with transportation, storage and value addition through the development of products and by-products that capitalize on the genetic diversity of bananas. Finally, marketing challenges are linked to asymmetric access to market information, limited understanding of consumer preferences and related trends and deficiencies in the marketing infrastructure.

Arguably, banana production constitutes the largest set of challenges, particularly from the perspective of smallholders who are constrained in terms of land, labour, capital and other resources. These challenges include a complex of biotic (black leaf streak, BXW, BBTD, Foc, weevils, nematodes) and abiotic stresses (nutrient deficiencies, drought stress), low genetic diversity of the planting material used, social constraints and climate variability and change. Most of these challenges, especially the biotic ones, cause yield losses of 50% or more, part of which could be addressed through investments in soil fertility and water management. There have been significant efforts to identify viable solutions at the global level. Research and development efforts have led to improved pest and disease management technologies, soil and water management techniques and post-harvest handling. However, persistent yield gaps can be observed in most smallholder banana systems. In fact, most of the recommended crop management practices are knowledge-laden, labour-intensive and costly to apply and, hence, outside the reach of many smallholders.

In addition, the structure and functioning of domestic banana markets, the design of improved technologies and business support services and policies rarely do justice to the diverse realities and needs of smallholders. Smallholder farmers are typically constrained in terms of access to information on latest technologies and the innovations required to keep pace with the dynamic environment of farming, markets and policies. A significant portion of current research focuses on technologies that are environmentally sustainable, but not necessarily apt for the diverse conditions of resource-poor farmers. For example, results of conventional breeding and genetic engineering may yield pest-resistant and climate-resilient varieties which, if not developed with a clear focus on end user preferences, will not be adopted by farmers at large scale; or, if requiring a combined application of fertilizers and pesticides, will not be accessible to many smallholder farmers.

It is therefore critical that future research and development efforts take the diverse production and livelihood systems of smallholder farmers as a point of departure, accounting for varied needs and aspirations within and across households. Gender- and age-differentiated development of technologies, with a clear view on current and anticipated future market trends, will go a long way to make agricultural technology development relevant to those who are at the beginning of the value chain. Such research efforts will also need to sensitize service providers outside of the value chain, including government agencies, NGOs and private firms, of the diverse realities and technology needs of smallholder farmers. This calls for action research approaches with strong participatory and gender-responsive elements, which can be linked to multi-stakeholder platforms and other mechanisms that bring together partners from public and private sectors and civil society for joint action and learning. Research findings can thus feed into processes of joint reflection, the definition of complementary roles and the design of effective scaling mechanisms for increased livelihood benefits based on the production, processing and marketing of banana. Finally, public and private policies and complementary institutional frameworks can support multi-stakeholder action and learning through innovative institutional arrangements, public-private collaboration and investments and, overall, the adequate provision of technical, business and financial services needed by smallholders and other key stakeholders in banana value chains.

6 Where to look for further information

Bioversity International, a member of the CGIAR, headquartered in Rome, Italy, will provide assistance in case of further research about the information discussed in this chapter. Bioversity International works with partners around the world to identify and deliver innovative solutions to ensure biodiversity nourishes people and sustains the planet.

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