Farmers' traits preferences for improved banana cultivars in Tanzania and Uganda

Noel Amos Madalla

Swedish University of Agriculture Science
Email: noel.madalla@slu.se; n.madalla@cgiar.org

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Noel Amos Madalla

noel.madalla@slu.se; n.madalla@cgiar.org

Supervisor:	**Prof. Rodomiro Ortiz, Sveriges lantbruksuniversitet, Sweden**
Assistant supervisor:	Prof. Rony Swennen, Catholic Universiteit Leuven, Belgium
Assistant supervisor:	Dr. Sebastien Carpentier, Bioversity International, Belgium
Assistant supervisor:	Dr. Eva Weltzien, University of Wisconsin-Madison, Germany
Assistant supervisor:	Dr. Allan Brown, International Institute of Tropical Agriculture, Tanzania

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Abstract

An understanding of farmers' preferences for new banana cultivars and their traits is critical for the development of cultivars that meet consumer needs and for successful adoption. The objective of this review was to evaluate the cultivar traits that influence farmers adoption of improved banana cultivars in Tanzania and Uganda. The study reviewed the literature on the introduction, evaluation, preference, acceptance and rejection of improved banana cultivars in Eastern and Central Africa (ECA), especially in Tanzania and Uganda. A total of 268 papers published from year 1930 to the present were collected using the advanced search databases of ScienceDirect, Web of Science, Scopus, ProMusa, Musalit and CGIAR. The results show that new cultivars have adopted both the formal and informal seed systems for introduction in both Uganda and Tanzania, and there has been a huge effort to develop the new cultivars locally through the establishment of local plant breeding programs. The traits farmers consider turned out to be more diverse than the formal understanding of the same traits by researchers. Cultivar preference varied primarily with use, market demand, agro-ecology, local culture and exposure to new cultivars, as well as socio-economic factors. For cooking bananas, farmers preferred sensory attributes (taste, flavor, texture and color). Bunch, hand (fruit cluster) and fruit characteristics plus resemblance with other traditional dessert cultivar was preferred for the dessert bananas, in addition to sensory attributes. The preference for juice, beer or wine cultivars focused on astringency, starch, plant vigor and bunch size. Irrespective of the end use, host plant resistance to pests and pathogens and marketability were important considerations to all types of bananas. Among other things, age, gender, dissemination strategies, extension services and years of farming experience, are the most important factors determining banana cultivars preferences among farmers. However, the gender aspect of banana trait preference was rarely considered in most studies and early maturity, a major focus of crop genetic improvement research, was found to have limited influence on the decision on cultivar use. Given the differences in consumption preferences, genetic composition, and the way genetic makeup interacts with the environment, no single cultivar equally supplies all the attributes needed by farmers. In addition, farmers use different cultivars under diverse ecological conditions, in various cropping systems and under different level of management. However, there is still a need for a participatory plant breeding approach involving farmers that enhances simultaneously production and consumption attributes. Such an approach is likely to promote adoption of hybrids banana cultivars in the region.

Keywords: Adoption, banana, cultivars, farmers, *Musa*, preference, traits

Table of Contents

List of Tables

List of Figures

1. Banana Synopsis

Bananas are grown in the tropical and sub-tropical regions of the world in more than 100 countries, where they are a major staple food crop for millions of people and provide a valuable source of income through local and international trade (Frison and Sharrock, 1998). The exact origin of banana in Africa is unclear, however, the recent discovery of banana phytoliths in Cameroon dating to the first millennium BC sparked a debate on the timing of the introduction of this important food crop in Africa (Lejju *et al.* 2006; Mbida *et al.* 2001; Mbida *et al.* 2000). Beed *et al.* (2012) estimated that bananas reached Africa between 2,000 and 6,000 years ago, long before the arrival of crops such as maize and cassava, while De Langhe and co-workers (1994–1995, 1999, 2000) hypothesized that this may have occurred about 3,000 years ago based on biological, linguistic, and prehistory evidences (Nayar, 2010). In the Great Lakes Region of East Africa (including Burundi, Democratic Republic of Congo, Kenya, Rwanda, Uganda and Tanzania) edible bananas would have entered from southeast Asia through multiple introductions between the first and sixteenth centuries A.D. (Price, 1995; Karamura, 1998; Nayar, 2010). In this region, banana is the mainstay for food and source of income to 50 million resource-poor farmers and worth some US$ 4.3 billion annually, equivalent to about 5% of the region gross domestic products (Beed *et al.* 2012). The East African highland bananas (EAHB, denoted *Musa* AAA-EA), which include the cooking types ('Matooke') and brewing types ('Mbidde'), dominate production in the region, and provide 3 to 22% of total daily calorie consumption estimated at 147 kcal per person and are grown on about 30 to 40% of utilized agricultural land (Kalyebara *et al.* 2007; FAOSTAT, 2014; Tinzaara *et al.* 2018). Being recognized as a second center of banana diversity (the first being the Indo-Malaysian region of Asia), EAHB plants grow well at altitudes of 1,000 to 2,000 m above sea level (masl) (Karamura 1998). However, above 2,000 masl, the majority of *Musa* cultivars do not perform well due to the low temperature (Kamira *et al.* 2016). The other cooking types include the plantains (AAB) and ABB cooking bananas such as 'Bluggoe' and 'Pisang Awak' both of these are more vigorous at lower elevations; i.e., below 1,200 masl for plantains and below 1,000 masl for ABB cooking types (Kamira *et al.* 2013; Blomme et al. 2020).

1.1 Banana production and use

The genetic diversity of banana in Africa is very small (De Langhe *et al.* 2001). It includes sterile triploid types of parthenocarpic, which share, along with all cultivated bananas, pulp development without seeds, a specificity that is the major domestication syndrome (Perrier *et al.* 2019). The AAA triploids of the Mutika subgroup, originally named Mutika-Lujugira by Shepherd (1957) and currently often referred to as EAHB, as edible derivatives of the wild species *Musa acuminata* (donor of the putative A genome), are very widely grown in East Africa (Perrier *et al.* 2019). In particular, Matooke and Mchare bananas are the dominant types in Uganda and Tanzania that are cooked before consumption. Non-endemic bananas include cultivars introduced by farmers from other regions of the world (referred as "exotics") and a variety of newly bred hybrids developed by Fundación Hondureña de Investigación Agrícola (FHIA) in Honduras and the International Institute of Tropical Agriculture (IITA) in Nigeria (Kalyebara *et al.* 2007). Exotic cultivars include beer and sweet bananas (AB, ABB, AAA genomic groups) and roasting bananas or plantains (AAB genomic group). Hybrids are tetraploid (AAAA, AAAB, and other tetraploid genomic groups) (Kalyebara *et al.* 2007). Bananas have perennial characteristics and can be grown for up to 50 years on the same piece of land if conditions are favorable (soil nutrients, weather, etc.). The cultivation takes place through clonal propagation with a space between plants of 3 by 3 m (Ouma 2009). Intercropping is a very common cropping system in East Africa and is practiced predominantly by most farmers due to decreasing land sizes and needs for food security (Ouma 2009). Beans (*Phaseolus vulgaris*), coffee (*Coffea arabica*), maize (*Zea mays*) and sweetpotatoes (*Ipomoea batatas*) are inter-cropped with the young banana plants when a banana field is established (Gambart et al. 2020). The intercrop would be phased out after a year; i.e., two cropping seasons, if the soil is still plentiful and farmers will begin to mulch the bananas. A few tree crops such as ficus (*Ficus nataliensis*), jack fruit (*Artocarpus heterophillus*), and pawpaw (*Carica papaya*) usually remained in the banana field to act as wind breaks (Gambart *et al.* 2020).

Unlike many staple crops, bananas deliver food throughout the year with production estimated at 10–12 million and 3 million metric tons in Uganda and Tanzania, respectively (BMGF, 2014). While ~2–3 million smallholder farmers dominate production on less than 2 ha of their land and most of the bananas produced are consumed locally, they make a major contribution to food and nutrition security for millions of people. Banana fruit and stem are used in a variety of ways in the Lake Victoria region of Uganda and Tanzania, but there are differences in consumer preferences due to differing habits, taste preferences and relative scarcity (Kalyebara *et al.*, 2007). As a result, multiple and distinct uses of a single cultivar can exist within and across communities (Nkuba *et al.*, 2003). In Tanzania, consumption preferences tend to be less specific to the type of use than in Uganda. The staple food in Tanzania is a combination of banana, meat/beans, and vegetables compared to the steamed, mashed banana (matooke), which is the staple food in Uganda. As food, banana has many nutritional benefits; i.e., starchy, pro-vitamin A carotenoids ranging from 0.23-59.56 µg/g dry weight (Ekesa *et al.*, 2012) with very high levels found in plantains and lower levels in other types of cooking bananas and commercial dessert (Davey *et al.*, 2009; Mbabazi *et al.*, 2020). They are also easily prepared in various ways; it can be boiled, steamed, mashed, baked, dried and pounded (FAO, 1990; De Langhe *et al.*, 2001). Banana can also produce by-products such as ropes, cover for fermenting cassava, nesting materials for egg-laying poultry, building materials for temporary shelters, sponges and roofing material, made from the dried leaves, leaf sheaths and petioles, the stalk attaching the leaf blade to the stem (De Langhe *et al.* 2001; Kamira *et al*., 2015). In addition, banana leaves are used for wrapping, packaging, marketing and serving of food (i.e., as plates) (Karamura, 1993; Kamira *et al*., 2015). The fruit peels are used as livestock feed, while the dried peels are used in soap production (Akinyemi *et al*., 2010; Kamira *et al*., 2015). In Tanzania, the banana plant provides medicines, feed for animals and decorations. Starch from the fruit can be used in industrial work, and leaves are used for making utensils, mats, thatching and owning a banana field increase social status to the owner (Nkuba and Byabachwezi, 2003).

1.2 Banana production constraints

In smallholder farming systems in the Eastern African highlands, where the crop is an important staple, pests and diseases are among the key reasons for low banana productivity, especially in central Uganda and northwestern Tanzania (Kagera and Kilimanjaro regions). These two regions produce 3.3 and 4 t ha^{-1} of bananas, respectively (FAOSTAT, 2016; Weerdt, 2003). However, the banana yields of Uganda (5–30 t ha^{-1} $year^{-1}$) and Tanzania (5.7 to 7.5 t ha^{-1}) are low compared to what they can potentially produce, with Uganda being able to yield 70 t ha^{-1} $year^{-1}$ and Tanzania 30 to 40 t ha^{-1} year-1 (van Asten *et al*., 2005; Barekye, 2009; BMGF, 2014). Banana bunch weights have dropped from 60 kg to 10 kg (Barekye, 2009). Furthermore, plantation life has decreased to less than five years, especially in the low-altitude areas, compared to the plantation life of 25–50 years or more in southwestern Uganda and southwestern Tanzania (Tushemereirwe *et al*., 2003; Nkuba, 2007). Uganda and Tanzania face similar production constraints such as pests (banana weevil and nematodes), pathogens (causing black leaf streak and banana bacterial wilt), low soil fertility, high production costs, marketing difficulties, and low genetic diversity (Gold et al. 1993; Nkuba, 2007). Black leaf streak or black Sigatoka leaf spot disease caused by *Mycosphaerella fijiensis* Moleret is considered to be the most serious constraints to banana production in the region (Swennen *et al.* 1989; Swennen and Vuylsteke, 1991; Mobambo *et al*., 1993; Craenen and Ortiz, 1998). The disease was introduced in Africa some three to four decades ago and spread rapidly, first in Central and West Africa and later in East Africa, causing severe leaf necrosis, which can lead to a reduction in yields of up to 50% (Wilson and Swennen, 1987). Banana bacteria wilt has spread across much of the Central Region in Uganda (Okaasai and Boa, 2004), while in Tanzania, fusarium wilt has devastating effects on Mchare bananas, especially in the northern regions of Kilimanjaro and Arusha. With the likely exception of banana bacteria wilt, whose impacts are both short-term and extreme, the magnitude of yield losses increases over time frames measured in years (Kalyebara *et al.* 2007). An important insect pest of banana in the ECA region is the banana weevil (*Cosmopolitus sordidus Germar*), whose larvae bore tunnels in the corm, thus weakening the plant. The arrival in Uganda of *Radopholus similis*, a parasite burrowing nematode, in the early 1960s and its subsequent rapid spread in many banana growing regions of the Lake Victoria region is a major component of the severe production difficulties currently facing the crop (Price, 2006). In several banana-producing regions of both countries, the vulnerability of pests and diseases appears to have been aggravated by persistent insufficient soil nutrient replenishment (Gold *et al.*, 1999; Meya *et al.*, 2020). In addition to the soil and biotic constraints, the productivity of bananas are further restricted by the following socio-economic constraints: (1) high production costs due to high labor, manure and mulch demands; (2) temporarily limited markets, in particular during peak harvests, due to the high perishability of the product; and (3) high marketing costs due to bulk nature of the crop and long haulage distances (Kalyebara *et al.*, 2007; William *et al.*, 2009). Furthermore, the long-standing practice of banana farmers has been the replanting of suckers of the same cultivar from fellow farmers inside or outside the group (Weltzien and Christinck, 2008). Inadvertently, this process also contributed to the spread of pests and diseases, since farmers did not recognize infested or diseased planting material or fully understand the life cycles and mechanisms of pests and diseases, especially given the continuous evolution of new breeds and pathogens. The complex interplay of biophysical factors, management practices, and the co-evolution of the banana plant and its constraints complicate determining the economic effect of even a single constraint. Furthermore, the coexistence of several constraints, whose separate effects are difficult to discern, complicates more the situation. It is equally difficult to isolate the ameliorating effect of improved management practices on individual constraints.

1.3 Improved banana cultivars and their introduction mechanism

Uganda has introduced a mix of short-term and long-term plans in an attempt to overcome banana production constraints in the region and developed genotypes that are resistant to local pests and diseases (Kikulwe *et al.,* 2007). The short-term plan involved the assembly of endemic and non-endemic germplasms for the assessment and selection of resistant or tolerant cultivars, including the importation of hybrids from other breeding centers such as FHIA and IITA. The long-term plan involves resistance breeding in the National Banana Research Programme, National Agricultural Research Organization (NARO), Uganda (Kikulwe *et al.*, 2007). While no systematic plant breeding was carried out in Tanzania until recently, banana growers have also worked to mitigate these pest and disease pressures by obtaining new, clean planting materials for endemic cultivars within and outside their communities, and adopting banana cultivars introduced by public and private extension services. The formal introduction of new banana cultivars into the region began in 1997, when KCDP was established (Weerdt, 2003; Gallez *et al.*, 2004). One of its objectives was to acquire, multiply, and disseminate new banana cultivars to farmers (Gallez *et al.*, 2004). On-farm testing of the new cultivars commenced in 1997 and was conducted concurrently with their multiplication and dissemination of planting materials to farmers in the region (Nkuba *et al*., 1999). The FHIA hybrids ('FHIA-1', 'FHIA-2', 'FHIA-3', 'FHIA-4,' 'FHIA-17,' 'FHIA-18,' 'FHIA-22,' 'FHIA-23,' and 'FHIA-25') developed by FHIA were the first to be introduced in Tanzania. Through trials, demonstration plots and farmers exchange of planting materials these hybrids were evaluated in four districts of Kagera region along with other cultivars such as 'Yangambi Km5', 'IC2', 'AA cv', 'BITA 3', 'Cardaba', 'Paka', 'Pelipita', 'Pisang Berlin', 'Pisang Ceylan', 'Pisang Sipulu', 'Saba' and cv Rose (Weerdt, 2003). The results of on-farm testing showed that on average the new banana cultivars yielded a bunch weight of 18.9 kg, compared with 9.7 kg for local cultivars, and are acceptable to farmers for their multiple uses be it cooking, dessert, roasting, brewing and good marketability (Byabachwezi *et al*., 1997). Around 2.2 million planting material from the new banana cultivars had already been distributed to farmers from 1997 to 2012 (Nkuba et al. 2002; Swennen, 2012). However, information gaps remain on the attributes that affect the acceptance of the new cultivars by farmers as well as the economic effects of adoption. Introductions of hybrids into Uganda during the 1990s targeted areas where pest and disease pressure was relatively high and farmers' crop yields were rapidly declining. The plants were evaluated in three phases: (i) organoleptic tasting; i.e., farmers assessment of cultivar taste (ii) on-station or selected sites where research-controlled evaluation trials were performed, and (iii) on-farm multilocational sites where farmers managed evaluation trials with backstopping from extension staff and researchers (Gallez *et al*., 2004; Kikulwe *et al*., 2007). The introduced cultivars were evaluated for pest and disease response, agronomic performance, and bunch use at all stages along with elite cultivars selected from endemic germplasm, which acted as controls. Multilocational, on-farm evaluation trials were performed in 20 districts of Uganda and the cultivars that were tested included AA cv. 'Rose', ABB 'Cardaba', 'FHIA-1', 'FHIA-2', 'FHIA-3', 'FHIA-17', 'FHIA-23', 'IC2', 'Pelipita', 'Pisang Berlin', 'Pisang Ceylon', 'Pisang Sipulu,' 'Saba', 'SH3436-9', and 'Yangambi Km 5' (Kikulwe *et al*., 2007). It was believed that new banana cultivars had a high yield potential and tolerance for one or more combinations of major banana production constraints, although in Uganda there was limited acceptance compared to Tanzania. The initial evaluation material for both countries was collected from national, regional and international breeding programs; from NARO of Uganda for 'Matooke' hybrids; from IITA for plantain (PITA) and banana (BITA) hybrids; from FHIA for FHIA hybrids and from Bioversity International's International Transit Centre (ITC), largely for landrace selections, as well as local research station and private tissue-culture laboratories (Karamura *et al*., 2016).

1.4 Plant breeding and varietal release process

Formal plant breeding programs have clearly made major contributions to cropping system productivity around the world (Weltzien and Christinck, 2008; Ortiz and Swennen, 2014).

As the science of genetics became better understood, banana breeders used plant genes to select specific desirable traits for the development of improved banana cultivars. The banana breeding programs in Africa, and East Africa in particular, has long been using crossbreeding methods to assess genetic variability and selection of superior recombinants by marker-assisted selection techniques or introgression of quantitative trait loci (QTL) (Ceccarelli, 2015). Their measure of efficiency has so far remained the number of cultivars released. This measure is favored for simplicity but ignores the fact that a cultivar produced by a breeder yield benefits only when it is adopted and grown by a farmer. If a cultivar is not adopted, breeders can still benefit if a cultivar is used as a parent material, but this benefit can only be expressed in the adoption of a cultivars from that parent (Ceccarelli, 2015). As often used in impact studies (Maredia and Raitzer, 2010), the ratio between the benefits produced by a new cultivar and the costs associated with producing that cultivar may be an alternative way of measuring the efficiency of a plant breeding program. Most of these research undertakings assume that a benefit may not occur unless the cultivar is adopted (Maredia and Raitzer, 2010), thus supporting the argument that adoption, rather than release, should be used as a measure of efficiency (Sall *et al.*, 2000). The number of cultivars released is therefore a gross overestimation of the efficiency of a breeding programme, and not an assurance of adoption. Lack of a functional variety release system has contributed to a delay in varietal releases (Setimela *et al.*, 2009). One factor that delay farmers' access to the benefits of plant breeding is unduly long procedures for releasing new cultivars. Varietal release systems in Tanzania allow for at least three seasons of value for cultivation and use (VCU) testing by the breeder, after which the cultivar is submitted for at least one season to the Tanzania Official Seed Certification Institute (TOSCI) for VCU tests and for distinctiveness, uniformity and stability (DUS) tests. TOSCI conducts the VCU and DUS tests in selected areas, depending on the areas recommended for the variety. When the evaluations are completed, the Variety Release and Seed Certification Committee will analyze the results to make recommendation for release (URT, 2010). In Uganda, the cultivars must pass the DUS and VCU tests before being released in the country. The DUS assessments are carried out by Ministry of Agriculture National Seed Certification Service Unit. The DUS data must be collected over two locations for a at least two seasons. The NARS breeder is responsible for collecting the VCU data across five locations for at least three seasons. When the data is available, the breeder shall prepare a proposal for variety release and present to the National Variety Release Committee (NVRC) composed of breeders, agronomists, biotechnologist, private sector representative, seed inspectors, and Director General of NARO (Ssebuliba, 2010). National variety release systems are also challenged by the need to provide farmers with access to a range of cultivars suited to specific agro-ecologies and meet the needs of various end-users.

1.5 Participatory and client-driven plant breeding

Participatory research breaks the linear mold of scientific study and focuses on a process of systematic reflection and intervention carried out with and by local people rather than on them. Farmers' active involvement in plant breeding has been extensively investigated and described as participatory plant breeding (PPB). PPB encompasses all approaches to enhanced plant genetics in the species through close collaboration between farmers and researchers (Weltzien *et al.*, 2003). The basic idea is to have different expertise and practical skills for farmers and researchers, as well as different approaches to problem diagnosis and resolution (Weltzien *et al.*, 2003). Witcombe *et al.* (1996) defined PPB as farmers' involvement in the selection process in the early (segregating) breeding program generations. In PPB, researchers, producers/farmers, consumers, extensionists, vendors, industry, and rural cooperatives have a research role in the breeding and selection process at all stages (Weltzien *et al.*, 1999; Ortiz, 2015). Such users become co-researchers as they assist setting goals, identifying specific breeding priorities, making crosses, screening germplasm entries in pre-adaptive phases of research, taking over adaptive testing and leading the subsequent process of seed multiplication and diffusion (Sperling and Ashby, 1999). However, in many breeding programs, cultivar testing remains primarily the domain of breeders and scientists testing cultivars in replicated trials managed and designed by researchers commonly known as on-station trials, and only the final testing of relatively few lines is conducted in farmers' fields (Weltzien *et al.*, 2003; Ashby, 2009). Particularly with regard to breeding economics, one of the most important features favored by many plant breeders is those cultivars that perform well in a wide range of conditions; i.e., "broad adaptation" (Weltzien and Christinck, 2008). However, under poor farmer's working environment with limited resources and marginal agroclimate conditions, these cultivars may fail. Practically speaking, the interactions between genotype and environment can be exploited positively if the selection is done in the target environment, especially in farmers' fields. This controversy culminated in an evolutionary paradigm of client-oriented breeding.

Client-oriented plant breeding traces its roots to farmers' participatory research approaches in the 1980s (Belay, 2009). The approach specifically takes into account the needs of end-users (farmers, processors and customers, etc.) in developing and evaluating of new cultivars. It allows varietal selection in targeted areas at cost-effective and timely manner and helps promotion of community seed production and community seed banks (Witcombe *et al.*, 2005; Ojulong *et al.*, 2017). A major component of client-oriented breeding is participatory varietal selection (PVS). PVS offers an opportunity for farmers to evaluate cultivars on their own fields using their local management practices (Witcombe *et al.*, 1999). It helps identify new cultivars that farmers prefer to grow for the traits they consider important and facilitates their adoption and dissemination resulting in positive and rapid impacts on food security and income (Joshi and Witcombe, 1996; Joshi *et al.*, 1997). It has been widely used and yet is among the powerful approaches for impacting and accelerating the process of varietal testing and release (Joshi *et al.*, 2012). A variety of PVS experiments have been carried out in banana. The most recent involved testing of the secondary triploid (3x) NARITA hybrid developed by the National Agricultural Research Laboratories Kawanda and the IITA Sendusu research station in Uganda (Tushemereirwe et al. 2015). NARITA hybrids are high-yielding and disease-resistant hybrids that are related to a group of cooking and juice bananas called East African highland bananas (EAHB). These hybrids were developed through crossing a female fertile EAHB cultivar (3*x*) and Calcutta 4, a diploid (2*x*) black leaf streak resistant accession of the wild species *Musa acuminata* ssp. *burmannica*. Thereafter, crossing of the resulting tetraploid (4*x*) hybrids was carried out with improved diploids (2*x*) to produce secondary triploids (3*x*) from which the NARITA hybrids were selected (Tushemereirwe *et al.*, 2015). Of the 27 NARITA hybrids, 25 have been evaluated over three crop cycles at the IITA Sendusu research station in Uganda. Their agronomic performance was compared to the one of the local cultivars grown by farmers, namely, the EAHB cultivar Mbwazirume. Their potential for adoption by farmers and consumers is being evaluated in a broader range of environments in Tanzania and Uganda (Tushemereirwe *et al.*, 2015).

1.6 Matooke product profiles

There must be specific targets for the type of product it is going to produce before a breeding pipeline is planned (Cobb *et al.*, 2019). This is known as the product profile in many breeding programs. In modern plant breeding, the emphasis is on the regularly updated use of product profiles and consultations between stakeholders to ensure that new varieties are optimized in compliance with the needs and desires of producers, consumers, traders, processors and others along the crop value chain (Ragot *et al.*, 2018). The product profile provides the plant breeder the ability to define the feature package required to replace a particular reference or target variety. Ragot *et al.* (2018), defined a product profile as a set of targeted attributes that a new plant variety is expected to meet in order to be successfully released onto a market segment. Breeding teams can make explicit advancement decisions when a potential new cultivar meets all the "must-have" criteria and has at least one "value-added" trait that distinguishes it on the marketplace (Cobb *et al.*, 2019). Typically, product profiles are designed to gather information on three aspects; identify existing reference cultivars already grown by the majority of farmers in the region; determine what farmers, buyers and other value chain players like about the cultivar; and make feedback about the reference cultivar from key stakeholders. Product profile seeks to focus breeding efforts on key traits that drive incremental value creation instead of an imaginative venture to develop a perfect variety (Cobb *et al.*, 2019). Matooke product profiles (Annex I) compare the new matooke hybrids to the common EAHB, Mbwazirume.

It specifies the criteria that the Matooke hybrids should have to meet the needs of the user(s). In terms of culinary attributes (taste, aroma, color, texture in the hand and mouthfeel) the hybrids should have a general acceptability score of at least 4 (on a 1–6 hedonic scale) with 'Mbwazirume' as a local check, and about 30% higher yield than the EAHB cultivar ('Mbwazirume') in a variety of soil and management conditions. Maturity days should range from 300 to 390 and be resistant to black leaf streak disease (https://breedingbetterbananas.org/). The product profile description assists breeding programs in the production of products with relevant characteristics but does not identify an absolute goal for any trait rather an advantage over the cultivars available in a particular target population of environments (TPEs).

1.7 The importance of understanding farmers' preferred traits

Although most of the hybrid's banana cultivars have high yields and are resistant to several main pests and pathogens affecting the region's banana production (Karamura *et al*., 2016), farmers' adoption depends on a combination of several important traits (Wanyama *et al*., 2013; Shiekh, 2015; Karamura *et al*., 2016). Numerous investigations have been conducted and researchers are still improving on the traits of the cultivars to influence adoption. In deciding adoption, however, it is especially important to consider farmers' perceptions of the new cultivars (Sharma et al. 2017). Most farmers assess a technology with criteria and objectives, which are different from the criteria that researchers prefer to consider. In addition, farmers grow crops that satisfy their diverse priorities and that once there is an agreement between these needs and attributes of cultivars, the result are cultivar preference and land allocation decisions (Wale and Mburu 2006; Acheampong *et al*., 2018). Bellon (1991) showed that farmers are not a homogeneous group and that their preferences and choice of technology are extremely heterogeneous. Farmers' preferences for cultivar characteristics are heterogeneous due to variations in consumption and production requirements. Farmers' preferences are governed by their expectations, their household contextual characteristics, and their institutional and socio-economic factors. In this regard, no single variety can meet all the needs of farmers (Bellon, 1996). Hellyer *et al.* (2012) noted that the selection of farmers depends on the perception of risk, the characteristics of the final product, the socio-economic variables, attitudes and perceptions, the socio-cultural environment and the amount of knowledge they have access to.

Farmers' past experience with other technologies may have been either positive or negative, and this is likely to affect their views on the adoption of new technologies. Drawing experience from other crops, e.g. cassava, some scholars considered cultivar choices as a collection of multiple characteristics (Wale *et al*., 2005; Edmeades, 2008). They argue that the cultivar traits or attributes are the performance characteristics of the plant cultivars that include both the production capacity of the plant and the consumption attributes of the product. For banana, such a collection of traits may include production characteristics such as host plant resistance to pathogens and pests, high yield, early maturity and adaptability to harsh environments, while the consumption characteristics may include traits such as taste, texture, aroma, color and other socioeconomic factors of importance that farmers consider before adopting the new cultivars. For example, if farmers do not perceive pathogens and pests in the same way as pathologists, this may have implications for their expectations of yield and decisions regarding pathogens or pest-resistant germplasm. Katinila *et al.* (1998) conducted a study on adoption of maize production technologies in southern Tanzania and showed that improved maize technologies that require little cash such as row planting, weeding are easily adopted by farmers, but only a few farmers have adopted more costly technologies such as fertilizers, herbicide, and disease control measures. The study also showed that many respondents were not familiar with improved maize technologies, especially the improved cultivars, use of fertilizers, ox-drawn implements, herbicide use and disease control measures. In Uganda, a study on *ex-post* impact of adoption groundnut cultivars on crop income and poverty was done by Kassie *et al.* (2011). Their analysis of 927 households from seven districts using cross-sectional data showed that the positive and substantial effect on crop income is consistent with the perceived role of new agricultural technologies in reducing rural poverty by increasing farm household income. Likewise, Kiiza and Glenn (2012) have also shown that access to market information has a positive and significant impact on the intensity of adopting improved seed for all crops while adopting improved seeds impacting on farm yields and gross farm returns.

Overall, three paradigms are commonly used to explain farmers adoption behavior and factors affecting technology adoption. The paradigms are; the model of innovation-diffusion; the adoption perception model; and the economic constraints models. Each focus on some elements of adoption such as the individual characteristic, the technology itself and the institutions process. The underlying assumption of the innovation-diffusion model by Rogers (1995) is that the technology is technically and culturally appropriate, but the problem of adoption is one of asymmetric information and very high search cost. According to this paradigm, access to information is the key factor determining adoption decisions. On the other hand, the adopters' perception paradigm, indicates the perceived attributes of the technology condition adoption behavior of farmers. This means that, farmers can subjectively assess the technology differently than scientists even with detailed farm household information (Kivlin and Fliegel, 1967). This perception is determined by personal factors such as human values, education and experience, as well as physical factors of the land and institutional factors such as awareness-raising through extension (Lynne *et al.*, 1988). The economic constraint model argues that short-term inputs such as access to credit, land, labor or other critical inputs limits flexibility of production and the decisions to adopt a technology (Adesina and Zinnah, 1993). The use of the three paradigms in modeling technology adoption improves the explanatory power of the model relative to a single paradigm.

In this context, it is therefore critically important to analyze the perceptions of farmers of new banana cultivars in order to ensure the acceptance and scaling-up of these cultivars. In addition, understanding the preference of farmers regarding the qualities of cultivars and how preferences along with specific characteristics of farmers' determine the variations in the levels of early adoption. This monograph therefore aims to respond to this specific research question by exploring cultivar features that influence farmers' adoption or non-adoption of improved banana cultivars in Eastern and Central Africa.

2. Bibliographic Approach

This study reviewed literature on the introduction, evaluation, preference, adoption and rejection of improved banana cultivars in Africa, particularly in Tanzania and Uganda. The open search for scientific articles from the Web of Science, Scopus, ScienceDirect, Google Scholar, Musalit, ProMusa and the CGIAR databases based on the terms "preferences of farmer traits for banana cultivars in Uganda," "preferences of farmer traits for banana cultivars in Tanzania," "adoption of banana cultivars in Tanzania and Uganda," "farmers preferences for banana culinary attributes," "participatory varietal selection" and "client-oriented breeding approach". These terms included words from the titles and from the keywords. A total of 268 scientific articles resulted from the open search. The research prioritized the review of papers recommended by different scholars, where empirical research links improved banana cultivars with traits that affect farmers adoption, as well as introduction paths and support mechanisms. In addition, particular attention was given to publications detailing previous similar attempts to analyze evidence that increased farmer or end-user participation in the selection and evaluation of new hybrids. In order to ensure that a comprehensive search was done, this study used systematic permutations of search terms to include the traits class; agronomic, sensory evaluation, social-economic factors, technological, etc., followed by common scientific name for the crop to confirm that no key investigations were missed. The main selection criterion for including an article in the detailed review was that it provided some evidence, quantitative or qualitative, for banana trait preferences. The data were summarized in order to provide meaningful results to address the key objective of the review; i.e., traits preferred by farmers to improved banana cultivars in Tanzania and Uganda.

Various different approaches have been used by scholars to define factors that decide the acceptance (reflecting the perception of farmers and consumers that a new cultivar is acceptable) and the adoption (reflecting the urge, initial decision or action to try a new cultivar) of bananas. Sensory assessments, including taste preferences and trait ranking, were used by Ankakwasa *et al.* (2020); Nowakunda and Tushemereirwe (2004) and Ssalli *et al.* (2010) to provide information on culinary qualities that influence consumer acceptance, while Smale *et al.* (2007) and Edmeades *et al.* (2006 & 2007) used checklists and cross-sectional questionnaire surveys to expose the perceptions, constraints and facilitators of the adoption and acceptance by consumers of new banana cultivars by farmers. Pricilla *et al.* (2019); Christinck *et al.* (2007); Rietveld (2017) and Kilwinger et al. (2019), conducted socio-economic research to include gender and cultural influences in the assessment of preferences for banana traits.

3. Results

3.1 Farmers preferences for yield potential versus fruit quality.

Sensory characteristics, including fruit softness, taste and yellow color of food, as well as agronomic characteristics, especially bunch size, are the most important criteria for the selection of farmers for banana cultivars in Uganda, particularly in the districts of Nakaseke and Mbarara (Ankakwasa *et al.* 2020). Farmers scored sensory attributes higher than agronomic attributes across districts. The most undesired attributes are small and short fingers, immature fruits, spotted or diseased fruits, brittle fingers, white or cream pulp, and hard to peel fruit (Ankakwasa *et al.* 2020). Smale *et al.* (2007) provided some useful tips on the adoption of new banana hybrids in Uganda and found that farmers regard high yield and cooking quality as the most important attributes. In cooking, endemic cultivars are regarded as superior, while hybrids are rated higher for bunch size and banana weevil resistance. Hybrids are ranked higher across all attributes than endemic types in Tanzania. However, the perceived differences in diseases between cultivars in Uganda are not statistically significant as compared to Tanzania. Ssali *et al.* (2010) present the findings of 18 conventionally bred 'Matooke' hybrids, the highland cooking bananas of East Africa, tested on-farm in the Nakaseke District of central Uganda. The hybrids were evaluated for consumer acceptability, black leaf streak resistance and agronomic performance. Culinary attributes were revealed to be more important to consumer acceptability than yield or resistance to disease. The local cultivar 'Mbwazirume' had a characteristic yellow 'Matooke' food color similar to that of hybrids 'M10',' M9" M14' and 'M2'. However, the hybrid 'M10' was not liked due to the pronounced and sticky placentas, a trait that most consumers dislike. With the exception of 'M3', 'M14' and 'M2', most hybrids were considered as less soft than 'Mbwazirume' after cooking. These findings contrast with those of Gold et al. (2000), who found that bunch size was ranked among the most important selection criteria for banana cultivars by farmers in Uganda, and it was also the single most important factor in three of the five regions in this country. It was ranked third in the central-northern region, behind marginal soil tolerance and drought, and next to crop longevity in the eastern region. For bananas grown for home consumption, most farmers reported taste as the key criteria for preference (Gold et al. 2002a). However, taste was rated as of moderate importance when the overall production goals were considered. Similarly, Nowakunda and Tushemereirwe (2004) noted that among 14 *Musa* cultivars introduced in Uganda, consumers rated new cultivars unacceptable for cooking attributes due to their high tannin content, hard texture and poor taste compared to local cultivars. Karamura *et al.* (2016) investigated the banana hybrids introduced in Africa, and their study found that 18 of the 44 cultivars introduced in Eastern and Southern Africa (ESA) were not adopted. Astringency, poor organoleptic qualities, the occasional appearance of seeds in the pulp, long pre-flowering periods and vulnerability to diseases were the main constraints to adoption. In particular, this was the case for plantain and cooking banana hybrids in highland regions. In addition, resistant FHIA hybrids were introduced and tested on-farm as an effort to solve the problem of black leaf streak in Uganda. The performance of these hybrids was fairly good for certain attributes. For example, 'FHIA-17,' 'FHIA-23,' and 'FHIA-1' got fair cooking quality ratings, while 'FHIA-1,' 'FHIA-3' and cultivars such as 'Yangambi km5' and 'Saba' received good juice ratings. However, numerous investigations showed that farmers have little adaptability to these cultivars, in particular with regard to the use and products that could be produced, as a result of which their uptake has remained poor (Ssemwanga et al. 2000). In Tanzania, FHIA hybrids have been acceptable to farmers for their various uses such as cooking, dessert, roasting, brewing and good marketability.

3.2 Farmers preferences and production constraints

Understanding the production constraints and desired crop variety traits of farmers is critical for the adoption and sustainable use of production technologies. A number of studies have documented that banana productivity is influenced by a number of variables, including abiotic and biotic stress, and their interactions and socio-economic constraints (Van Asten et al. 2005; Wairegi et al. 2010). A study carried out by Nkuba (2007) to evaluate the adoption and economic effects of new banana cultivars on the livelihoods of farmers in the banana-based agricultural systems of the Kagera region revealed that the perceptions of farmers willing to embrace new banana cultivars vary by village and depend on three types of factors. The first is the degree of production constraints they encountered. The second is the form and depth of dissemination, including information provided to farmers in the region. The third is the external variables that affect price and demand. Most farmers agreed to plant new banana cultivars in areas where banana production had been significantly affected by banana constraints, while most farmers refused to plant new banana cultivars in areas where conventional banana cultivars were still producing enough bananas, but waited and watched their output from volunteer neighbors. Gold *et al.* (2002) conducted a survey of 24 sites (five farms per site) found in Uganda's primary banana-growing regions, which found that pests were considered by most farmers to be a significant constraint on highland banana production and pest resistance as an important and desirable quality. However, many of these farmers found all highland banana cultivars to be susceptible and were unable to differentiate between their available cultivars in terms of pest resistance. As a result, pest resistance has always been assigned a comparatively low weight, given its perceived importance. In the central region, where banana production experienced major declines and limited market opportunities, the most critical parameters were taste and tolerance of marginal soils and drought (Gold *et al.*, 1999). The principal components analysis for the selection of the most important factors per location showed similar findings that longevity, marginal soil tolerance and drought tolerance were the most important selection criteria across the country. Differences in the dissemination strategies, biotic stresses, expectations of farmers and the geographical size of the region are likely to contribute to the marked differences in the rate of adoption between Uganda and Tanzania. For example, the acquisition of planting materials for new hybrids was highly variable between Tanzania and Uganda. Ugandan farmers traversed an average of 15 km for new planting material, compared to less than 3 km in Tanzania, which suggests a high fixed transaction cost that may also impede adoption in Uganda. Smale *et al.* (2001) reported that farmers choose cultivars based on a collection of attributes that best respond to their production constraints, meet consumer preferences and satisfy specific market requirements. Edmeades *et al.* (2006) reported that the improved banana cultivars were preferred by farmers because they produce relatively higher and stable yields, which could be mainly attributed to their disease resistance (black leaf streak, fusarium wilt and banana bacterial wilt). Based on the results of the on-station testing and the evaluation by farmers of the banana cultivars introduced through the KCDP project, some of the 25 banana cultivars imported into the Kagera region were found to be adaptable especially in terms of pest and disease resistance (Kilkulwe *et al.,* 2007). These include 'FHIA-1', 'Yangambi Km 5', 'Pelipita', 'SH3436-9', 'FHIA-17', and FHIA-23. However, 'FHIA-2', 'FHIA-3', 'Cardaba', 'Pisang Berlin', 'Pisang Ceylon', and 'AACV Rose' were not adopted because of being not tolerant of local pests and diseases (Kilkulwe *et al.,* 2007). Edmeades et al. (2007) used a treatment model when controlling for other variables in order to explain the determinants of adoption and the impact of adoption on expected yield losses from pests and diseases. Their results indicate that the intended effect of increasing hybrids on production vulnerability has been achieved, justifying research efforts aimed at improving resistance materials.

Figure 1. Banana production and use in ECA

(A) NARITA field in Mbarara, Uganda. (B) Farmers marketing East African highland bananas (EAHB) in Uganda (photo: Niel Palmer, CIAT). (C) EAHB Banana bunch. (D) Cooked *Matooke* EAHB. (E) Male and female farmers take part in the selection of the most preferred NARITA hybrids to be taken for further on-farm testing.

3.3 Market influence on farmers' preferences for banana cultivars

Product attributes are seen as criteria by which consumers shape perceptions, create behaviors and establish intentions to buy a product (Sabbe *et al.*, 2009). Bananas are often sold as bunches and to a lesser degree as fingers (Odeke *et al.*, 1999). The acceptability of a new banana hybrid by consumers depends on a combination of attributes such as bunch weight, number of hands, fingers and sensory attributes (Kikulwe *et al.*, 2011a). As a result, the selection criteria often represented individual farmers and household preferences, and varied from region to region, depending largely on the social and economic factors of the area. In south-west Uganda, the majority of farmers preferred cooking types sold to traders who transported them to the Kampala, Mbarara and Jinja urban markets (Gold et al. 2002). Farmers and traders in this region preferred cultivars that produced large and compact bunches. Compactness makes it possible to carry many bunches in a truck, while the big bunch attract higher prices on the market. Country-wise bunch weight was the most important criterion mainly for commercial purposes, while taste was reported by most farmers as the key factor for bananas grown for household consumption. The selection criteria also represented the expected end-use in high banana commercial growing areas of Uganda. Farmers selected high-yielding (large bunch size) cultivars for market because of greater acceptability to traders and higher cash returns, and lower-yielding cultivars of better taste for home consumption, while traders perceived big fingers, big bunches, maturity, shiny light green peel color, good appearance (fresh, appealing, good finger formation) and compact bunches/fingers as the top five characteristics important for their customers (Ankakwasa *et al.*, 2020). Other mentioned characteristics which cater for the diverse customers served include long fingers, medium bunches, medium sized fingers, straight fingers and varieties that are soft when cooked (Ankakwasa *et al.*, 2020). Karamura *et al.* (2016) who studied banana hybrids introduced in Africa reported that, in the case of dessert bananas targeting local and regional markets, farmers selected for bunch, hand and finger characteristics, plus similarity with other traditional dessert cultivars, in addition to sensory attributes. Gold *et al.* (2002) performed a combined principal component analysis (PCA) to define the most important traits across the region. The weighing criteria for this component were bunch size and marketability, which explained 20% of the PC2 variance with eigenvectors of 0.44 and 0.43, respectively. The two criteria were related, as stated by the farmers, to the fact that the size of the bunch largely determines the marketability of the cultivar. These two attributes were therefore the most important selection criteria in the south-west region, where commercial goals for banana production are important. In areas where the crop is grown primarily for home purposes with a low market potential for bananas, food security attributes predominate, and subsistence farmers continued to maintain a high proportion of small-bunch early maturing cultivars to provide them with a steady supply of food throughout the year. Banana cultivars attributes have also been shown to be affected by market prices. Akankwasa *et al.* (2013) investigated consumer willingness to buy East African Highland cooking banana hybrids in Uganda and the findings show that hybrid “M2” would attract significantly higher prices in the Eastern region compared to the Midwest, whereas consumers in the Western region would pay the lowest price. Participants in the Eastern Region would pay a significantly higher price to Hybrid “M9”, followed by the Western Region, with the Central Region being the lowest. Of all hybrid cultivars, consumers were able to pay a considerably higher price for Hybrid “M9” compared to Hybrid “M17”. This is certainly due to its ideal characteristics, such as, taste, texture and color of food. With the exception of the gender of the respondent and the willingness to buy “M14”, the willingness to purchase and the socio-economic characteristics of consumers also indicate that there have been major differences in all characteristics.

3.4 Gender and banana trait preferences

Gender is one of the variables hypothesized to influence the use of banana hybrids as well as a tool to help define the effects of hybrid use on vulnerability (Edmeades *et al.*, 2007). The effect of gender-differentiated trait preferences on the adoption of banana cultivars has rarely been investigated and most studies have recorded conflicting evidence of the different traits that males and females prefer. Edmeades *et al.* (2007) investigated the use of hybrid cultivars in Kagera Region, Tanzania, and found that the gender of the banana farmer reflects preferences for banana attributes and use. Their analysis showed contrasting preference for hybrid use between males and females, with females concentrating mainly on home use purposes, while males considered hybrids useful for selling and brewing beer. The gender of a farmer does not appear to be related to hybrid adoption when other variables, such as education, age, household size, etc., are considered (Edmeades *et al.*, 2007). This may be the result of the active participation of both men and women in different aspects of banana production and marketing. Christinck *et al.* (2017) examined the gender differentiation of farmer preferences for cultivar traits and found that, men are more interested in production and marketing traits and women are more interested in production and use-related traits. Traits preferred by women were more related to post-harvest processing and food preparation, as these are traditionally women's activities in many cultures. Further, women often mentioned traits related to family food security, e.g. earliness, multiple harvests and production assurance throughout the years. Similar traits preferences are mentioned when men and women are faced with similar constraints. Variations can occur for men and women who farmed under different conditions and have different production roles and responsibilities for different purposes (Weltzien *et al.*, 2019). Marimo *et al.* (2019) also found that the preferred traits varied between the gender groups; women preferred risk averting traits like short duration, drought tolerance, disease resistance and cooking qualities (taste, color, softness) while male preferred market-related traits, especially high yield and big bunch size. Weltzien *et al.* (2019) and Marimo *et al.*

(2019) found that, traits preferred by farmers were correlated with the roles of men and women in the banana value chain. Their research also emphasized that the same traits and cultivars are preferred by different actors in the value chain, regardless of whether they are men or women. Both women and men consider the compactness of the bunch to be a negative attribute, as it makes de-clustering and de-finger difficult, however, traders prefer this trait for easy transportation of bunches to the market.

3.5 Farmers trait preferences and cultivars' release process

Understanding the preferred attributes of banana cultivars by farmers and the degree to which they are incorporated into the varietal release systems of the country is crucial for adoption. The importance of on-farm varietal testing has been highlighted in many investigations with limited emphasis on attributes related to post-varietal release adoption. Sanya *et al.* (2017) evaluated the effects of the adoption of new banana hybrids in central Uganda and found that the varietal release criteria mainly focused on the technical attributes of the new cultivars, while the rigor of the preferred attributes of the farmers are not fully considered. For example, when the cultivar 'M9' was released in 2010 due to its disease resistance and tolerance to pests and drought, which increases plantation longevity, farmers called it 'Kiwangaazi' in the local language (Luganda) which literally means 'long-lasting.' This name has been simpler for farmers as it identifies the major challenges affecting banana production, but the complexity arises when the varietal release authorities decide to assign a cultivar a different name that does not have any meaning for farmers. The cultivar 'M9' was released in 2010 as 'KABANA 6H' by the MAAIF National Variety Release Committee. Information from the FGDs with farmers indicate that a name of a new cultivar has an effect on its use and farmers were unable to understand the naming process of new cultivars. The naming criteria of farmers differed from the NARO nomenclature as they associate it with the attributes of the cultivar. Farrington and Martin (1988) found that farmers are usually involved in traditional crop improvement only in the final stages of cultivar testing, generally after cultivars have been identified for release. There is also little to no input from farmers about the management of these trials or the tested genotypes. The evaluations of the tested genotypes by farmers are generally not pursued, or if they are, they play little or no role in the varietal release and recommendation decision-making process. Moreover, Thiele et al. (1997), Fukuda and Saad (2000) have shown that farmers are only involved in the final stages of the evaluation of the few near-finished or advanced cultivars just prior to their official release; this act hinders the integration of farmers' perceptions and traits that are potentially important to them and consumers but for which economic value may be more difficult to assess. Virk et al. (1995) also found that farmer-relevant traits are rarely considered while promoting cultivars for release. The promotion procedure essentially involves comparing the yield of new entries with checks or trial means. Similar procedures are followed when cultivars are considered for release. Limited attention is paid to other important traits. For example, although short plant height is an important trait for farmers in central region Uganda, cultivars will only be promoted if they satisfy the criterion for bunch yield. If promotion criteria are to give due importance to farmer-relevant traits, selections must be made based on multiple trait selection indices.

3.6 Cultural context and cultivars preferences

Little is known about the effect of cultural practices on newer crop innovations, such as improved banana cultivars. The few studies available investigated the influence of cultural practices on local banana cultivars with limited focus on improved cultivars (Rietveld *et al*., 2016; Kikulwe *et al*., 2018; Kakuru *et al*., 2018). The findings showed that farmers prefer cultivars closely linked to their beliefs, traditions and norms (Rietveld, 2017). In Uganda, bananas are considered more than just food, or a source of income, and are rooted in local context and culture. For example, farmers prefer banana cultivars 'Bogoya' and 'Ndiizi' because they have good leaves for steaming a popular locally food "Matooke" (Kilwinger *et al.,* 2019). The leaves are believed to give the "Matooke" a nice aroma and a pleasant yellow color. Banana leaves are also useful for mulching and for wrapping bunches when transported to the market. 'Gonja' and 'Mbidde' banana cultivars are preferred for their medicinal properties and used to hasten the healing of the navels of newborn babies and to prevent vomiting (Kilwinger *et al*., 2019). Farmers in Tanzania prefer Mchare banana cultivars found mainly in the Kilimanjaro region for the preparation of "Machalari" (G. Kindimba, personal communication), a food with special respect for the traditions and cultures of Chaga's tribe. Apart from being a usual food for everyday consumption, it is often cooked when a household receives a guest, during wedding ceremonies and on holidays at the end of the year. 'Ndizi Ng'ombe' banana cultivar is preferred for making "Mbege" a common local beer and one of the primary sources of family income. In Uganda, it is traditional to bring a banana bunch to social gatherings including weddings. Furthermore, when a baby girl is born, the placenta is buried under the mat of 'Nakitembe' and the placenta of a baby boy under the mat of 'Mbidde' or Kayinja (Kilwinger *et al*., 2019). The placenta is seen as the twin of the unborn child and needs proper burial. Cultivation practices in Uganda are subject to traditional rules and beliefs in the sense that a plantation is considered a living organism worthy of special respect. In Tanzania, a farmer's choice to grow a certain cultivar is mainly based on traditional customs and less on market demand; a situation which leads to farmers failing to sell their harvest particularly during peak seasons (Nkuba and Byabachwezi, 2003). This situation on the other hand helps to reduce genetic erosion of banana diversity. Smale *et al.* (2007) noted that most farmers maintain banana plantations mainly to meet food security and cultural needs, only entering the market on a sporadic basis when opportunities and needs arise. There is a much smaller but increasing share of farmers whose main goal is to produce for the banana market. Clearly, decisions on the use of production and technology and the response to market opportunities and signals are distinct for these two groups.

3.7 Characteristics of the household and preferences of banana cultivars

The characteristics of the household have an immense influence on the use and preference of hybrid bananas. The findings showed that the probability of a family using banana hybrids increased with school years (Smale *et al.*, 2007). More educated households were more likely to accept new banana hybrids, partly affected by the inclusion of topics related to the management of agricultural production in the school curricula. Wealthier households, especially those who own livestock, were shown to prefer hybrids because of the complementarity between the use of hybrids and the supply of fodder for animal feed. The size of land holdings is another physical characteristic of the farm and a significant measure of the wealth and scale of production, both of which have a positive effect on the use of hybrids (Akankwasa *et al.,* 2013). The years of experience of banana farmers and the number of extension visits are measures of human capital acquisition. Human capital gained was positively related to hybrids use with associated benefits in terms of food supply and income generation (Smale *et al.*, 2007). Exposure to banana hybrids and elevation were two factors also affect hybrid adoption. The power of the exposure variable in capturing the impact of the use of formally distributed hybrids was compromised by an informal means of transferring planting material from one farmer to another. The treatment effect of exposure was dissipated with as many as 20% of farmers in non-exposed areas reported growing banana hybrids (Smale *et al.*, 2007). Geographical location also had an immense effect on the usage pattern of hybrids, with 96 per cent of households growing banana hybrids living in low-elevation areas where the pest and disease pressures are higher, and the program intervention would have the highest impact. Akankwasa et al. (2013) also noted that household characteristics such as age, education and characteristics such as good taste, texture, and color are likely to have a positive effect on the purchase of most banana cultivars of the hybrid. However, the factors negatively influencing the likely purchase of hybrid bananas when found on the market were the gender and regional location of the respondents.

3.8 Farmer trait perception for adoption of improved banana cultivars

Farmers' perception of a new cultivar has a significant impact on its adoption, and thus the involvement of farmers in cultivar development seems to be the most appropriate strategy to increase the likelihood of adoption and hence the efficiency of the breeding program (Adesina and Baidu-Forson, 1995; Sall *et al.*, 2000). Their perception influences their behavior in terms of cultivar choices, which, in turn, have an effect on farm conservation and on crop diversity (Wale, 2008). For example, farmers will continue to use traditional cultivars to the extent that adaptability is their concern, and if they see local cultivars as better adapted to the local environment (pests, diseases, erratic rainfall, hailstorms, etc.). Or they will maintain these cultivars if they appreciate the role of conventional cultivars in their livelihoods, e.g. stabilizing income. Since yield is not the only criterion for acceptance, even if the yield of improved cultivar is similar to that of local cultivar, farmers may prefer to adopt the new cultivars if they perceive more benefits. Kagezi *et al.* (2012) analyzed the adoption of new banana cultivars in Uganda and found that compared to local cultivars, new or bred banana cultivars tend to be well-represented, but farm and agro-ecological planting is very limited. This is due to farmers' long-standing perceptions of inferior taste and poor marketability associated with new banana cultivars. In Tanzania, farmers' overall perception of new banana cultivars is that they are acceptable and have good marketability and various uses, such as cooking, dessert, roasting and brewing (Byabachwezi et al. 1997; Nkuba, 2007), making 29 per cent of every 177 households planted at least one new cultivar (Weerdt, 2003).

3.9 Diversity of EAHB cultivars and farmers trait preferences

Swennen and Vuylsteke, 1991; Baker and Simmonds, 1952 and Gold *et al.* (2002) have shown that there are more than 70 highland banana cultivars in East Africa, with the greatest diversity of unique adapted bananas being enjoyed by populations in Uganda and Tanzania. The high degree of diversity of banana cultivars is observed at the micro level; i.e., on single farms (Edmeades *et al.*, 2006). In a typical household in Uganda, at least 7 banana cultivars are simultaneously grown, compared to an average of 10 cultivars per household in Tanzania (Edmeades *et al.*, 2007). Major cultivars appear to be fairly uniformly distributed across households and most of the cultivars farmers grow are native to East Africa. The reason farmers retain so many cultivars at the same time is that farmers consider that the various banana cultivars have distinct advantages and disadvantages in terms of consumption as well as production needs. For each farmer, the demand for attributes is unique and varies with the characteristics of the farmer. Sanya *et al.* (2000) explored production and consumption characteristics that affect farmers' decision to grow a particular cultivar in Central Uganda, and their results showed that new cultivars were prized for their pest and disease tolerance and thus contributed to the survival of banana plantations. It was also noted that the hybrids were tolerant of poor soils and drought. Such attributes are critical when a farmer chooses a diversity to grow in order to avoid total failure. Hybrids' high yield potential will for instance, help farm households ensure their food security. On the other hand, cultivars serve as living stocks, mitigating the reliance of farmers on cumbersome, longer-distance exchanges of planting materials to obtain the cultivar with desired traits (Edmeades *et al.,* 2007). In Tanzania, resistance to black Sigatoka, weevils, and *Fusarium* wilt, as well as cooking and culinary quality, are the main attributes farmers considered, which are thought to influence the diversity of bananas on farms (JAICAF, 2010). Differential host plant resistance to a variety of biotic stresses is to some degree conferred by the various genomic structures of farmer-grown cultivars. Farmers in Tanzanian consider hybrids to be more resistant to black Sigatoka, and to weevils in both Uganda and Tanzania. Endemic cultivars were perceived to be more resistant to *Fusarium* wilt, as is expected given the genomic group. A t-test comparing the predicted yield losses for endemic and hybrid bananas indicates that they are on average less susceptible at a 10 percent significance level providing some evidence that farmers perceive benefits from the introduction of hybrids (Edmeades *et al.,* 2007).

4. Discussion

The traits preferred by farmers in Uganda and Tanzania for the adoption of improved banana cultivars are multivariate and involve factors other than yield-related characteristics. In view of the varying consumption preferences, the genetic structure and the relationship between genetic make-up and the environment, not a single cultivar offers all the attributes desired by farmers. The relative importance assigned by farmers to different attributes influences the trade-offs they make when choosing the type and number of cultivars to be grown, which are noted to have an effect on their consumption and preferences. Farmers have a good understanding of their growing environment and the key traits that new cultivars must possess, particularly as they attempt to adapt to their complex production systems and the stress typical of their local conditions. As farmers employ numerous cultivars in different cropping associations under varying ecological conditions and at different levels of management, knowing their general production goals will be a general criterion for successfully developing plant cultivars that meet the requirements of the farmers (Weltzien and Christinck, 2008). This is critical in terms of their livelihood and survival strategy and the value of farming, as well as cultivation methods, uses and the key constraints to increase yields or generate income

Moreover, according to partial technology adoption literature, farmers do not adopt new technologies and immediately drop old ones for reasons of safety-first behavior and learning (Smale *et al.*, 1994). It is believed that the integration or mixing of resistant hybrids with local cultivars improves yield stability and thus promotes the continued production of local cultivars. Some reviews have also shown that, in order to capture both desirable production and consumption traits, farmers who have adopted improved cultivars often continue to plant local cultivars (Smale and Heisey, 1995; Brush, 1995). Consistent with the empirical evidence from the extant literature on adoption, traits related to yield, plant growth, marketability and host plant resistance to pest and pathogens were the key determinants for farmers adoption decisions in this review. Farmers in Uganda and Tanzania look at the overall plant characteristics and not at the individual plant trait, and they assess the total value of the cultivar as they see it, which enables them to predict how it may perform under a specific condition. These assertions are similar to those reported by David *et al.* (2002) that farmers' adoption decisions are influenced by both production and consumption characteristics of crop cultivars and that, awareness of the traits preferred by consumers is therefore essential for any crop improvement program and provides market signals for producers. Smale *et al.* (2001), also noted that farmers choose cultivars based on a set of attributes that best respond to production constraints, meet consumer preferences and satisfy specific market requirements.

Cultivar characteristics and all these individual criteria must be met before they will accept a new cultivar. Moreover, gender-specific traits and those related to the intrinsic quality attributes and socio-cultural values, such as food taste, texture, flavor and color and which are highly valued by farmers are partially considered when selecting most hybrids for advancement and release. Failure to integrate these attributes in banana cultivars development and selection processes would probably explain the low rate of adoption in the region. The results are consistent with those stated by Ceccarelli (2015) that most researchers are largely accustomed to productivity-related indicators, ignoring available literature showing that yield is not always the key driver of adoption. However, they differ to those reported by Christinck *et al.* (2017) that, women and men sometimes do not need separate cultivars, but cultivars that have preferred traits for both genders. In this way, breeding will better contribute to addressing gender-differentiated trait preferences if it is part of such integrated approaches and relies on careful diagnosis of the diverse strategies, desires and priorities of men and women working on bananas. In this way, if breeding form part of such integrated approaches and rely on careful diagnosis of the diverse strategies, needs and goals of men and women working on banana can best contribute to addressing gender-differentiated trait preferences. This would actually require a sound methodology and gender-inclusive participation structure when planning for varietal improvement programs at various levels –namely, internationally, regionally, nationally, and locally.

Farmers in Uganda and Tanzania like improved cultivars and local cultivars because of their specific trait benefits. The hybrid cultivars yield well and are resistant to diseases and pests, as well as tolerant to drought but the taste deviates from that of local cultivars. On the other hand, one of the main features of local cultivars, in comparison with hybrids cultivars, is their better compatibility with local farming systems (e.g. the ability to withstand environmental stresses such as lack of water or nutrients, drought, poor soils, etc.), and socio-economic structures, which is reflected in specific characteristics such as yield stability, pest and disease resistance, good food taste, preferred flavor, texture and color of the food when cooked. Important as yield may be for food production, other traits may additionally determine overall suitability. To the farmers, it is not just about the pathogen and pest resistance but also to what extent the new cultivars meet the use and consumption attributes inherently present in their local cultivars. Glenna *et al.* (2011) assessed how farmers matter in shaping agricultural technologies and they had similar findings about end-users having an interest in a technology for reasons other than what the technology developers intended.

The decision-making process for the adoption of new banana cultivars depends on both intrinsic factors, such as knowledge, perceptions and attitudes, and extrinsic factors, such as farmers' characteristics (age, education, social networks, agricultural experience), biophysical characteristics (farm size, elevation), farm management characteristics (wealth, land tenure, labor availability) and external (contextual) factors (sources and type of information, market access, etc.). Similar results have been stated by Feder *et al.* (1985) and Smale (2007) that the adoption by smallholder farmers of a new technology largely depends on the degree to which the new technology meets the underlying social conditions and intrinsic attributes. Ankakwasa *et al.* (2013) also showed that consumer characteristics such as age, education, residence, income and gender, among others, were important factors in explaining the probability of consumer use of hybrid bananas in Uganda. In their study, the age of the respondent was statistically important and positive for ‘M9’ and ‘M17’ hybrids, whereas higher education consumers were more likely to use banana cultivars.

In view of the reproductive properties of bananas, planting-material distribution systems developed by farmers themselves tend to be most suitable, enabling the gradual and systematic dissemination of improved cultivars to farming communities. However, review of existing dissemination models and mechanisms will be required to verify which ones are more cost-effective, efficient and why. The overwhelming significance of the farmer-to-farmer exchange of planting material and information explains the role of village social structures in evaluating whether new cultivars are being used. Similar results have been reported by Katungi *et al.* (2006) that the social structure of villages affects the use of prescribed practices by individual farmers for the management of bananas. This influences farmers’ views about the practices (perceptions) based on their felt needs and prior experience. A major food staple, bananas are also sold on local markets, but their perishability and transport costs lead to risks for traders and difficulties in connecting supply areas to areas of high demand. These attributes are not preferred by most banana growers. The prospects for processing have not been fully explored. Exports are mainly regional or geared towards a niche market for migrants.

Further, the fallacy of using the number of cultivars released as a measure of efficiency of the breeding program is often due to the weakly scientific basis on which cultivars are released such as poorly planned and unrepresentative trials. This assertion offers the importance of assessing the criteria used by breeding programs and national varietal release systems as to how they adhere to the needs and desires of farmers. In addition, farmers must be properly informed about the performance of new cultivars, and systems need to be in place to provide farmers with this knowledge, or to provide them with the opportunity to test cultivars prior to release. Tripp *et al.* (1997) also indicated that inappropriate selection of test sites coupled with prolonged cultivar testing programs, and unequal distribution of resources at various trial stages, low participation of farmers, and weak cooperation between national and regional testing systems all contributed to the problem of low cultivar adoption.

In summary, farmers' perceptions of the preferred traits and traits of hybrid banana cultivars have been examined as a deciding factor in the adoption decision-making process. Not only the adoption, but also the rejection (before or after use) of banana cultivars. Farmers' decisions to adopt new cultivars involve a series of sub-decisions on whether or not to try out new cultivars and whether or not to fully replace old cultivars. Farmers often adopt improved banana cultivars if they find only desirable traits or combinations of traits better than and not found in their local cultivars. This is because choosing between two presents trade-offs. The rate of adoption increases as hybrids are tested and evaluated in the real farmers' environment in order to validate their advantages and increase farmers' understanding of the benefits of these cultivars. Despite the vast body of literature showing breeders rarely consider farmers preferred traits, as in the case of banana culinary attributes. Translating and integrating that knowledge into something that breeders can measure is not always a priority agenda in most banana socio-economic studies. This is common for traits such as texture and flavor, which are difficult to quantify, and so research should focus on exploring this potential knowledge for the achievement of plant breeding initiatives. The promotion of new banana cultivars and the awareness of farmers to their good qualities should be therefore a priority for research in the development of new banana cultivars. However, it takes 15–20 years to change people's perceptions in order to accept new technology. Local cultivars will not necessarily be replaced by improved banana cultivars but are likely to settle in new niches. The gender aspect of the preference for banana traits was minimally considered in most of the reviews. Further research should focus a great deal on leveraging the potential characteristics of men and women in order to increase the potential for adoption. In comparison with Uganda, limited research has looked at the trait preferences of banana farmers in Tanzania. In the context of the banana breeding program recently established by IITA at the Nelson Mandela Institute of Science and Technology in Tanzania, this information is important for the feeding of breeding initiatives and the provision of the right cultivars or hybrids to farmers.

5. Outlook

This review provides useful information on the traits of importance to end-users and the key criteria that farmers and consumers use for adoption or rejection of new banana cultivars. It also informs breeders and policymakers on farmers' preferred characteristics for the new banana hybrids to influence adoption. This information is important in informing the banana breeding strategy and early selection process. At the global level, the adoption of improved agricultural technology is considered critical to the attainment of Sustainable Development Goals (SDGs), especially SDG 2 to "End hunger, achieve food security and improved nutrition, and promote sustainable agriculture". Therefore, to counteract the low adoption rates and ensure food security, efforts should be made to help institutions and stakeholders to define the characteristics and traits of the new cultivars preferred by farmers, consumers and other stakeholders along the value chain (formalized as a "product profile"); combined with extensive, field-based evaluation programs to identify the most promising cultivars suited to various agro-ecological environments and farming systems; and linkages to seed systems in-country, in which national regulatory agencies take responsibility for the registration of new cultivars, while various public agencies, community organizations and private seed companies undertake the multiplication, distribution, and promotion of cultivars to farmers.

6. Conclusion

This study was motivated by the assumption that, if the priorities, needs and desires of farmers are valued and better understood by researchers, successful and sustainable recommendations can be made, thereby increasing the probability of farmers adoption of new banana cultivars. Farmers have useful knowledge on the attributes, and insight into the trade-offs they are willing to make when adopting a new cultivar. These considerations, however, are hardly integrated into the breeding goals. A partial analysis of the available literature on improved banana cultivars in Tanzania and Uganda shows that farmers preferred both the production and consumption attributes of new banana cultivars. The review found that most hybrids were rated high by farmers in terms of production characteristics such as good agronomic and yield attributes as well as pathogen tolerance, but inferior in terms of consumption characteristics such as taste, flavor, and food color, particularly when compared to the local control, with the exception of the hybrid 'M9' which was closest to the reference cultivar with regard to all cooking quality traits. On the other hand, the constraints faced by farmers in banana production affect the adoption of the cultivars. Compared to areas with low disease pressure and where conventional banana cultivars still yield enough bananas, farmers are obliged to plant new bananas in areas with high pest and pathogenic pressures. Dissemination pathways, including on-farm research, multiplication and demonstration sites, seminars prior to the delivery of planting materials and the provision of extension education, were found to be important determinants of farmers acceptability of cultivars, especially when they are provided with appropriate first-hand experience of growing new cultivars and learn directly from their own experience. Results further revealed heterogeneity in gender preferences. Compared to men's preference for marketing and production attributes, women farmers have typically great preference for cultivars with food and cooking quality attributes. As the improved cultivars are shown to be inferior in terms of food quality attributes, the impact of gender on cultivar adoption remains uncertain. The fact that farmers' preferences for cultivar traits determine to a large extent their choice of a cultivar, and that they attach substantial weights to both production and consumption traits, allude to the need for breeding cultivars that have the potential to cater for multiple uses. The reason is that banana market chains are not well established and farmers face difficulties in selling their produce. This is perhaps one of the key reasons behind the low adoption rates of high yielding improved banana cultivars. These results have important implications for breeding priority setting, and targeted diffusion of improved banana cultivars in Uganda and Tanzania.

7. Ongoing PhD research

7.1 Problem description and rationale

The Great Lakes Region of East and Central Africa (ECA) is a major production area of bananas with higher per capita consumption than anywhere else in the world of about 400 to 600 kg per person (Karamura *et al.*, 1998), and much higher than cereals crops; i.e., 130–150 kg per person (Abele, 2007; Mkonda and He, 2017). With an annual production of 20.9 million t, valued at US$ 4.3 billion, banana is a key crop in the livelihoods of many people (Tushemereirwe *et al.*, 2015). Unlike many staple crops, bananas deliver food throughout the year, making them an ideal crop for household income, food and nutrition security (Tushemereirwe *et al.*, 2015). In Uganda and Tanzania, banana is a major food staple as well as an important cash crop in the local economy (Kalyebara *et al.*, 2007). In Uganda, banana provides an estimated 30% of calorie intake and 5% of fat intake of the population (Kalyebara *et al.*, 2007). Similarly, in Tanzania, bananas are the staple food of an estimated 20 to 30% of the total population (Walker *et al.* 1984). In the banana-based farming systems of the Kagera and Kilimanjaro regions, about 70 to 95% of households grow bananas for food or cash on an average field size ranging from 0.5 to 2 ha per household (Byabachwezi and Mbwana, 1999).

Despite the importance of banana in the ECA region, production has been recorded at 9% of their yield potential of 60 to 80 t ha^{-1} (Tushemereirwe *et al.*, 2015). The annual yield per hectares in the five East African countries is as follows; Uganda 5.5 t ha^{-1}, Tanzania 8.4 t ha^{-1}, Rwanda 8 t ha^{-1}, Kenya 4.5–10 t ha^{-1} and Burundi 5 t ha^{-1} (BMGF, 2014; Ireri, 2015; Kamira *et al.*, 2013; Gaidashova *et al.*, 2010). The threats of pests (banana weevils and burrowing nematode); and pathogens such as black leaf streak disease, fusarium wilt or Panama disease and banana bacterial wilt are named to be the major constraints posing a severe threat to the future sustainability of banana production across the region with potential of further destabilizing both food security and household incomes (Tushemereirwe *et al.*, 2015; Van Asten *et al.*, 2005; Barekye, 2009). The pathogens also adversely affect the post-harvest fruit quality and is the main reason for the banana fruit to be rejected by exporters (Gold *et al.*, 1993; Arias *et al.*, 2003).

Research shows that the current banana bunch harvests (hereafter yield) in Uganda stand at 5 to 30 t ha^{-1}year^{-1} and are further declining, compared to the potential yield of 70 t ha^{-1} year^{-1} (Van Asten *et al.*, 2005; Barekye, 2009). In the major banana-producing areas of Tanzania, available data also indicate that production has remained largely stagnant or low during the 1990s (MAC, 2000; Nkuba *et al.*, 2003). Major banana-production constraints faced by farmers in Tanzania are similar to those faced by farmers in Uganda and include declining soil fertility, increased pressure of pests and pathogens, and poor crop husbandry (Kalyebara *et al.*, 2007). Respectively, in both countries, low production has been associated with low application of fertilizer which resulted to lower levels of nitrogen and potassium, but more importantly inadequate management (Gold *et al.*, 2000). A number of socio-economic factors, ranging from resource availability (declining farm sizes, outward labor flows, and declining household incomes) to infrastructure and institutional factors (access to roads, credit facilities, and extension) attributed to decline in management in the farmers' fields (Gold *et al.*, 2000). All these factors have further contributed to food shortages, thus putting consumers heavily dependent on bananas at food and income insecurity, particularly in areas where the crop is regarded as a staple food and source of income.

In the last two decades, the introduction of high-yielding banana hybrids through development of host plant resistance to several pathogens and pests has become one of the strategies to revive the low banana production caused by pest infestations and low soil fertility (Nkuba, 2015; Tushemereirwe *et al.*, 2015). As a result, various banana cultivars have been introduced and released in Tanzania and Uganda in the last 10 years. The data show that out of the 31 cultivars introduced, six were officially released in Uganda including: 'FHIA-1' and 'FHIA-3' that were released in 2000; 'FHIA-17', 'FHIA-23' and 'Yangambi Km5' released in 2004; and 'M9' and 'M2' released in 2010, the latter two being locally bred (Karamura *et al.* 2016). In Tanzania, through the Kagera Community Development Programme (KCDP), six banana cultivars were introduced that proved adaptable to farmers. These include 'FHIA-1', 'Yangambi Km5', 'Pelipita', 'FHIA-17', 'FHIA-23' and 'SH3436-9' (Kikulwe *et al.,* 2007). These cultivars were bred for host plant resistance or tolerance against black leaf streak, banana weevil and parasitic nematodes, mainly burrowing nematode, all of which remain major problems to the banana farming in Uganda and Tanzania (Karamura *et al*., 2016).

IITA and NARO have played a leading role in the development of 27 EAHB hybrids namely NARITA with host plant resistance to black leaf streak disease and other pests plus good agronomic characteristics such as high yielding. These cultivars are noted to have the potential to raise productivity from 30 to 40 t ha^{-1}. Out of 27 secondary triploid NARITA hybrids, 25 were evaluated on research station in 2010 for three crop cycles at Sendusu, near Kampala in Uganda (Tushemereirwe *et al.* 2015). One of these hybrids have been formally released as new cultivars in 2010 by NARO and are already being grown by 15% of banana farms in Uganda (Tushemereirwe *et al*., 2015). On the other hand, various newly-bred banana hybrid cultivars have been introduced in different eastern and central African countries since the 1990s. 'FHIA-1', 'FHIA-3', 'FHIA-17', 'FHIA-23', 'M2', 'M9', 'M19', 'M20', 'M25', 'M27', and 'M30' are other examples of the few improved banana hybrids introduced and currently grown by farmers in different regions of Uganda and Tanzania.

Despite this progress, the rate of adoption by smallholder farmers has remained low compared to potential available at the local community. Slow adoption by farmers has continued to minimize benefits and impacts spillover to the local communities and therefore increase the risk of food insecurity and vulnerability. Selection criteria have mainly focused on high yield, early maturity, host plant resistance to pathogens and pests instead of a product profile[1] (Table 1; Matooke breeding profile, 2018). However, many other preferred traits by end users such as *inter alia* flesh color, ease of peeling or feed for animals determine the acceptance and adoption of a banana cultivar (Marimo *et al*., 2019). These traits can be a challenge for breeders to meaningfully assess unless there is a research partnership with farmers and social scientists. The assessment of the bred banana hybrids on-station is essential for early selection of priority traits, although it does not provide enough information about the needs and preferences of farmers. Incorporating farmers' needs is essential not only for the purpose of influencing adoption, but also for enhancing the efficiency and effectiveness of breeding efforts, particularly for variable and marginal environments where adoption of improved cultivars from plant breeding programmes has been limited. Some scholars (Jusu, 1999; Maru-Aduening *et al.* 2006) argued that, farmers have their own indicators of performance and quality, which sometimes are not well anticipated by researchers. They are relatively consistent in their selection and their

[1] Desired characteristics of new cultivars preferred by farmers, consumers and others along the value chain for a target cultivar to breed. It assists breeders to develop new cultivars with preferred attributes by end-users.

selections correspond with their needs, preferences and sometimes their cultural values and local environments. Consequently, most technologies developed without the participation of farmers' have failed to address the rural poverty issues in Africa appropriately.

The researchers' selection criteria may not fit to all agro-ecologies. These agro-ecologies vary with respect to soil type, moisture and temperature regimes, fertility condition and the onset, intensity and duration of rain as well as social, cultural and economic dimensions, where farmers thrive to grow their bananas. Environments may sometimes change fruit quality in banana. Castelan *et al.* (2018) confirmed environmental effects on banana, whereas the presence of a natural ecosystem surrounding a crop area influences plant health and fruit postharvest behaviour. The study considered parameters such as life, carbohydrate profile, and pulp firmness for banana fruits harvested from Near-Natural Forest (NF) and Distant-Natural Forest and the results showed that, bananas harvested from Near-NF have higher green life and a more homogeneous profile during ripening compared to fruits harvested from Distant-NF. Moreover, Vermeir *et al.* (2009) studied the influence of origin on ethylene treated samples originating from Panama and Colombia and the results revealed that banana from Colombia had a higher sugar concentration, resulting in an increased soluble solid content (SSC) and produced more volatiles compared to banana from Panama which contained more acids and were harder. Apart from the mentioned environmental factors and understanding of farmers preferred traits, a number socio-economic and institutional factors also limit adoption. This include low income and lack of education among farmers, poor promotion and weak extension systems, expensive and insufficient quantities of planting material, and delays in distributing approved planting materials. Hence, participatory approaches are essential to help in understanding these variations and optimize chances for wider adoption of the NARITAs.

Participatory variety selection (PVS) is the selection process by farmers on their own fields of finished or near-finished products from plant breeding programmes (Witcombe *et al.* 1996). These include released cultivars, breeding materials in advanced stages of testing, and well-characterised germplasm such as advanced non-segregating lines in inbreeding crops, or advanced populations in outbreeding crops (Witcombe *et al.* 1996). It is a process whereby breeders and agronomists obtain feedback from the potential end users about which cultivars perform well on-station and on-farm. It is also a means for social scientists to identify the cultivars that most male and female farmers prefer, including the reasons for their preference and constraints to adoption. PVS requires information on the social, economic, and cultural dimensions in the varietal selection process. This will also introduce the farmers to the many ways in which socio-cultural aspects are built into various activities to determine the most suitable cultivar to adopt under their farming environments and crop husbandry practices. Hence, the primary objective of this study is to obtain a better understanding of farmer cultivar selection criteria's and perceived cultivar performance in the banana-growing regions of Uganda and Tanzania, whereas farmer's objectives, growing conditions and production constraints vary by region. In so doing, a gender-sensitive PVS will be used to evaluate 20 to 24 NARITAs hybrids for their agronomic performance and consumer acceptance both on-station and in a wide range of target end-user environments and users' preferences. The ultimate goal is the understanding of preferences and needs for specific traits and trait combinations by a diversity of farmers in the two countries and provide input towards refining product profile for future banana breeding efforts. Moreover, assessment of agronomic performance of NARITAs with ultimate goal to optimize adoption chances, thereby enhancing yield and productivity, and eventually contributing to income and food security of the target populations. Such information on selection criteria and cultivar performance can assist in the development of site-specific cultivar recommendations and identify traits of importance for consideration by breeders during the breeding process.

7.2. Goal and objectives

7.2.1. General objectives

To obtain a better understanding of farmer cultivar selection criteria and perceived cultivar performance in the banana-growing regions of Uganda and Tanzania.

7.2.2. Specific objectives

1. Evaluate the agronomic performance and yield [2]stability of NARITA hybrids across crop cycles in research-station trials and on-farm in five sites in Tanzania and Uganda;
2. Better understand the preferences of farmers for banana cultivars in Tanzania and Uganda, and the criteria they use for adoption or rejection;
3. Assess banana varietal performance and edaphic-climatic factors contributing to the genotype-by-environment interaction (G×E) for plant growth and yield parameters;
4. Optimize methods for assessing agronomic performance of banana hybrids in on-station and on-farm trials, particularly for validating the quantifying of bunch weight of EAHBs using non-destructive field observations[3]

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[2] It can simply be regarded as above-average performance in an appropriately chosen set of environments. Though, consistency of performance over the set of environments has also to be considered. A cultivar is also considered stable if it has adaptability for a trait of economic importance across diverse environments.
[3] Wairegi, L.W.I., van Asten, P.J.A., Tenywa, M. and Bekunda, M. 2009. Quantifying bunch weights of the East African Highland bananas (*Musa* spp. AAA-EA) using non-destructive field observations. Scientia Horticulturae 121:63–72. http://dx.doi.org/10.1016/j.scienta.2009.01.005

7.3. Research hypotheses

Hypotheses tested in this research are:

Hypothesis 1: Adoption of improved banana cultivars by farmers is affected by a participatory varietal selection (PVS) approach

Hypothesis 2: The farmers will adopt improved banana cultivars only if they find desirable traits or combinations of traits better than and not found in their local cultivars, since choosing between the two presents trade-offs to farmers.

7.4. Expected outcomes and policy relevance of the study

This PhD research will contribute on the following research outputs:

- Understanding of traits of importance to end-users and use this to orientate banana breeding strategy and early selection process
- Understanding of key criteria that farmers and consumers use for adoption or rejection of new banana cultivars to guide breeding investments
- Allow selection and site-specific cultivar recommendations of widely adapted and stable genotypes, in this case NARITAs, across a wide range of environments
- Allow male and female farmers to be part in decision making and selection of the most preferred NARITA hybrids before officially released in Tanzania and Uganda
- Underpin and increase the efficiency and effectiveness of participatory variety selection in the end user target environment therefore influence adoption
- Provide a framework that can be used to evaluate other crops utilized by different target end users in different environments
- Work with breeders and policymakers on farmers' preferred hybrid banana traits and farmer characteristics that will influence adoption of the hybrid bananas
- Help the inclusion in the breeding process of the traits that are potentially important to farmers and consumers but for which the economic value may be more difficult to assess
- Provide necessary information to countries varietal release process to ensure that the new cultivars are tested to meets the needs and preferences of the farmers and at the same time safeguarding the environment, health and biosafety.

Table 1: Matooke product profile

Trait	Trait category	Market priority	Target trait level	Selection objective	Desired short-term impact	Desired long-term impacts
Taste, aroma, colour, texture in hand and mouthfeel	Quality	1	A general acceptability score of at least 4 (on a 1–6hedonic scale) with 'Mbwazirume' as check	Reach threshold	1	2
Yield	Agronomy	1	30% greater than EAHB cultivar (e.g. 'Mbwazirume') across a range of soil and management conditions	Maximize	3	1
Maturity	Agronomy	2	Early (300 - 390 days)	Minimize	9	7
Plant stature (girth at 1m/height ratio)	Agronomy	2	A ratio of at least 0.15	Maximize	7	5
Plant height	Agronomy	2	Less than 350 cm	Minimize	10	4
Suckering behavior	Agronomy	2	75% follower sucker growth at harvest	Maximize	12	12
Resistance to black Sigatoka	Agronomy	2	INSL at flowering of 70% and above	Reach threshold	4	6
Resistance to weevils	Agronomy	2	Resistance higher than that of the susceptible check 'Kibuzi'	Maximize	8	9
Resistance to *Radopholus similis*	Agronomy	2	Resistance higher than that of the susceptible check 'Valery'	Maximize	5	8
Resistance to BXW	Agronomy	2	Sources of resistance to be identified	Opportunistic	11	6
Bunch orientation	Agronomy	1	Pendulous score of 1 or 2	Opportunistic	6	10
Drought tolerance (water productivity)	Agronomy	3	Tools to be developed	Reach threshold	12	11
High ProVitA content	Agronomy	1	Average carotene (µg/100 g) higher than 150	Opportunistic	2	3

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