Complexity of agricultural technology development processes: Implications for uptake of new hybrid banana varieties in Central Uganda

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Abstract: Low uptake of improved technologies remains a challenge to enhancing agricultural productivity and food security in developing countries. This paper uses the agricultural innovations systems approach to analyse how the recently released hybrid banana varieties (HBVs) were developed, and how the interplay between processes and actors affect their uptake in central Uganda. The study used a qualitative research design employing a case study approach. Data were collected through 20 key informant interviews and 5 focus group discussions with purposively selected actors and farmer research groups respectively, and analysed using thematic-content analysis in NVivo. Results indicate that the process of developing HBVs is dominated by agricultural research institutions with limited involvement of other actors such as farmers, private sector and extension staff. Further, there is limited integration of social aspects including gender in the banana technology development process. The study, therefore, recommends use of inclusive participatory approaches to enhance technology uptake.

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PUBLIC INTEREST STATEMENT
Technological advancements have the potential to accelerate agricultural transformation in Sub-Saharan Africa. As such, National Agricultural Research Systems in the region have embarked on the task of developing new technologies to increase agricultural productivity levels, but uptake of these technologies remains low. In this paper, we provide insights on the interplay between processes and actors in technology development and how this accounts for uptake. We established that many gaps exist in the process of developing new hybrid banana varieties that ultimately impact technology uptake. We thus suggest a change in technological development processes which aims at enhanced involvement of diverse actors and multi-level prioritization of both technical and social aspects including gender. Researchers need to put in place a rigorous process for prioritization of end-users’ needs and preferences at the different stages of technology development.
in breeding of HBVs while paying attention to gender-specific preferences and the
intrinsic quality attributes such as food colour, texture, flavour and taste since these
are critical drivers for uptake of the new banana varieties.

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1. **Introduction**

The rapidly increasing population in Africa, amidst declining agricultural productivity, poses complex
global challenges associated with poverty and food security (AGRA, 2017; Food & Agriculture
 Organisation of the United Nations [FAO], 2015). The projected rapid population growth in Africa will
be the leading cause of food insecurity due to increased food demand (Hall, Dawson, Macdiarmid,
Matthews, & Smith, 2017). Thus, agricultural research systems, as one of the key actors in enhancing
food security, need to reorganise in an efficient and sustainable manner to address the food-related
challenges. Many actors expect agricultural technologies to address the constraints associated with
low productivity as well as contribute to narrowing of the food gap and overall agricultural develop-
ment (Beintema & Stads, 2014; USAID, 2011). Therefore, acceleration of the rate of technological
change is expected to propel the sustainable intensification of production systems (Godfray et al.,
2010). To this end, several national agricultural research systems in Sub-Saharan Africa have gener-
ated technologies with a potential to enhance agricultural productivity. However, the uptake of
these technologies, particularly improved crop technologies, is disappointingly low (AGRA, 2013;
World Bank, 2008). To achieve increases in productivity, agricultural research systems need to em-
brace innovative strategies and approaches in technology development. Systemic approaches and,
specifically, the use of the Innovation Systems Approach (ISA), have been recently embraced in
technological innovation processes (Hall, Bockett, Taylor, Sivamohan, & Clark, 2001; Klerkx & Leeuwis,
2009; van Mierlo, Leeuwis, Smits, & Woolthuis, 2010).

Adoption of the ISA resulted from failure of the linear approaches that viewed knowledge develop-
ment and application as separate activities carried out by researchers and farmers respectively.
Researchers were considered as specialists or “knowers” of what was good and who developed tech-
nologies that were “perceived” to address the needs of the end-users. Described as a one-way pipe-
line, from researcher to extension to farmer (Biggs, 1990; Douthwaite et al., 2017), researchers were
expected to develop new technologies and transfer them to extension workers, who in turn trans-
ferred them to farmers for adoption. Unlike the linear approach, ISA is holistic and designed to en-
hance development and uptake of technologies via iterative involvement of diverse actors. The
approach focuses on integrating different actors, their resources and knowledge; and institutions
that condition behaviours and practices in the process of innovation. Spielman, Ekboir, and Davis
(2009) argue that the future of technological development and delivery systems depends on the ef-
iciency and effectiveness of actors in innovation systems. Owing to the importance of systemic
approaches, the National Agricultural Research Organisation (NARO) in Uganda has emphasized the
need to engage different actors within and beyond the National Agricultural Research Systems
(NARS) in its Research and Development (R&D) activities (National Agricultural Research Organization,
2008). The aim is to enhance the relevance of research, particularly the technological outputs, such
as new varieties for national priority crops (Ministry of Agriculture, Animal Industry & Fisheries, 2010).

Banana (Musa spp.) is one of the most important priority crops with potential to contribute to food
security and income in Uganda (Smale & Tushemereirwe, 2007). Although banana occupies the larg-
est cultivated area among staple food crops, with more than 75% of the farmers growing the crop,
its production has over time declined due to a complex of production constraints, mainly pests and
diseases (Gold, Karamura, Kiggundu, Bagamba, & Abera, 1999; Kubiriba, Tushemereirwe, Kenyon, &
Chancellor, 2013; Tushemereirwe, Kashaija, Tinzaara, Nankinga, & New, 2003). To reduce the impact of these constraints, NARO, through the National Banana Research Programme (NBRP), has taken technology generation as an efficient pathway for increasing banana productivity (Ministry of Agriculture, Animal Industry & Fisheries, 2010; National Agricultural Research Organization, 2012). The NBRP focuses on restoring production of bananas, especially of the East African Highland cooking bananas, locally known as matooke, through development and promotion of new technologies. A diagnostic study conducted in the 1990s revealed that the Black Sigatoka disease (Mycosphaerella fijiensis) and pests, mainly nematodes (Radopholus similis) and weevils (Cosmopolites sordidus), were the most important threats to banana production, especially in central Uganda (Tushemereirwe, Gold, Speijer, & Holderness, 1993). Given that at the time there were no available resistant or tolerant cultivars, various banana plantations were devastated and almost wiped out in the region. The NBRP therefore embarked on a long-term strategy of developing new banana genotypes with resistance and/or tolerance to the identified pests and diseases. The breeding efforts that started in 1994 resulted in development, release and promotion of various technologies, including the new Hybrid Banana Varieties (HBVs)—also referred to as the matooke hybrids.

While efforts by the NBRP have led to development of these new varieties, their uptake remains low, especially in central Uganda (Kagezi et al., 2012). Past studies on hybrid bananas in Uganda have focused on socio-economic factors that influence adoption (Akankwasa, Ortmann, Wale, & Tushemereirwe, 2013; Edmeades, Smale, Kikulwe, Nkuba, & Byabachwezi, 2007; Kagezi et al., 2012; Karamura et al., 2016). Results of these studies partially indicate failure of HBVs to meet end-user expectations. This raises questions as to how the new HBVs were developed from the Agricultural Innovation Systems (AIS) perspective, particularly, the processes and extent to which actors were involved in the process. While studies on Agricultural Technology Development (ATD) have tended to focus on farmers’ participation in breeding programmes (Ashby, 2009; Smale & Tushemereirwe, 2007; Sperling, Loevinsohn, & Ntabomvura, 1993), little is known about key processes that are crucial to enhance uptake. From a systems perspective, there was a need to explore how various actors are involved in Banana Technology Development (BTD) and the extent of their involvement in the process. Akankwasa et al. (2013) argue that farmers’ involvement in banana varietal improvement and development is vital for meeting their preferences and could result into decisions for variety uptake. However, little is known about how this should happen, at what stages and in which critical processes to facilitate the choice decision of new banana varieties.

To understand the dynamics and complexities embedded in BTD and to establish the relationship between the process and uptake of new HBVs, this study uses the AIS framework and the Innovation System Functions Approach in particular (Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007; Klerkx & Leeuwis, 2009). The approach is key to understanding processes that are important for the success of any Technological Innovation System (TIS) (Wieczorek & Hekkert, 2012). The processes are categorized as functions of the innovation system. Since the functions do not operate in isolation of structures, the analysis further integrated the structural dimensions of TIS (actors and institutions) that shape and influence action in the BTD process. Knickel, Brunori, Rand, and Poost (2009) note that innovation is systemic in nature and is an outcome of collective actions that depend on the social structure within which innovators operate. The extent and level of involvement of diverse actors promotes exchange of new knowledge and learning that is essential for innovation capacity (Spielman et al., 2009) and consequently determines the output. Therefore, this study analyses how the BTD process that led to new HBVs was organised and with which implications for uptake. In this study, the BTD process typifies an innovation process and provides a basis for analysing how banana research was designed and implemented to facilitate technology uptake. The main research question was: how do the processes and actors in banana varietal development contribute to the output, and with which implications for uptake? Exploration of the BTD process provides insights on how it was organised to shape and influence uptake of new technological innovations, which is critical to achieving the post-2015 SDGs.
2. Methodology

2.1. Study design and area
A qualitative research design employing a case study approach (Sarantakos, 2012; Yin, 2009) was used to understand the constructed realities of technology development and how these vary within a given context. A case study is suitable when faced with the “how” and “why” questions with little researcher’s control over events in a real-life context. This design was thus suitable given the purpose and objectives of this research. The study focused on understanding how the new HBVs were developed based on the value chains approach to analyse the key processes, activities and actors at each node of the BTD process.

The study was conducted in central Uganda where a decline in banana production has been experienced over the years. The districts of Nakaseke, Luwero, Wakiso and Mukono were purposively selected for this study on the basis of their prior participation in banana R&D activities. The choice of these districts was also based on the efforts by the NBRP to improve banana production in the region.

2.2. Sample selection and data collection
The study population included different actors (individuals and organisations) along the nodes of the banana technology development chain. These included researchers, extensionists, banana farmers, private tissue culture laboratory operators/entrepreneurs, and policy makers. Project and program documents were reviewed and exploratory meetings held with researchers from the NBRP to guide the selection of the study population. Actors (including farmers) involved in the BTD process for new HBVs were identified and listed in each category to form a sampling frame. Representatives of each actor category were purposively selected by virtue of their experiences, involvement and knowledge of the process that resulted into the new HBVs.

Data were collected using qualitative methods mainly key informant interviews and focus group discussions (FGDs). Twenty purposively selected actors, including agricultural researchers, extensionists, producers/farmers, training institutions, private tissue culture laboratory operators/entrepreneurs and policy makers that were involved in the process of developing new HBVs were interviewed. Five FGDs consisting of 7–9 farmers each were conducted with banana farmer research groups. The primary data were supplemented with review of NBRP documents. Semi-structured instruments consisting of open-ended questions were used as interview and discussion guides during the key informant interviews and FGDs, respectively. The semi-structured format of instruments allowed for extensive probes, breadth of responses and emergence of a wide variety of viewpoints (Sseguya, Mazur, Wells, & Matsiko, 2014). The interviews were conducted face-to-face with actors. In-depth interviews aimed to provide a description of actors’ lived experiences during the process. The research team moderated the FGDs to ensure that each participant was given a chance to express their views while a rapporteur recorded notes to make sure that all participants’ views are captured. A digital voice recorder was used to back up the recorded notes during the interactions with respondents.

To ensure content validity, the instruments were developed after extensive review of documents and related literature. In addition, the instruments were subjected to technical review by peers and University supervisors for their opinion on the representativeness and suitability of the questions. Reliability was achieved by triangulation of data sources and collection methods.

2.3. Analysis
The data collected using a digital recorder were transcribed verbatim using express scribe transcription software (Ver 5.78). Where the local dialect (Luganda) was used during the interview, it was translated into English and transcribed for analysis. The transcripts were imported into NVivo software (Ver 10) for coding and analysis. The analysis followed a thematic content analysis approach which results in a descriptive presentation of data. Both deductive and inductive approaches to
coding were used. The deductive approach was based on the themes that were developed ex-ante guided by information that was required to support the study objectives while the inductive approach aimed at creating new and emerging themes. After the coding, further searches through the data and analysis were done to identify emerging patterns from the categories. Sections of each transcript were coded under an appropriate theme and direct verbatim quotes from the interviews extracted for use when discussing the results.

3. Results and discussion

The analysis revealed four themes that underlie the BTD process: stages, activities, actors and their roles. These themes are discussed simultaneously based on the different BTD processes while identifying the underlying gaps in the process and how these gaps affect the uptake of new HBVs.

Information from key informant interviews indicates that the process that led to development of the new HBVs can be described as a five-stage process involving; (1) setting the research agenda; (2) breeding; (3) trait evaluation and selection; (4) variety naming, release and registration; and (5) promotion and commercialization. Figure 1 presents a summary of the key processes, particularly the key activities and actors at each of the stages in the development of new HBVs.

At each stage, different activities were conducted guided by various aspects as in any ATD process. These activities necessitated the involvement of different actors to perform functions aimed at fulfilment of the innovation objective. Across the stages of the BTD, different types of actors were involved. The actors involved can be clustered in four domains based on elements of an AIS (Rajalahti, Janssen, & Pehu, 2008): education and research (research and training institutions; intermediary (extension agents, donors); enterprise (banana farmers and private tissue culture laboratory operators/entrepreneurs; and demand (regulatory and policy agencies) domains.

In most innovation processes, various actors come on board with differing interests and expectations either as individuals or for the organisations they represent. A combination of the processes, activities, actors and their roles resulted into complexities at the different stages of the process. However, the level of complexities differed at the different stages of the BTD process and these mainly resulted from the nature of activities as well as differences in interests and capacities of actors.
3.1. Stage 1: Setting the research agenda

The process leading to development of the new HBVs started in the early 1990s with planning. Planning mainly aimed at setting the research agenda and comprised of three main activities: identifying the problem, defining the intervention strategy and forming the required partnerships for implementing the strategy (Figure 2). During this phase, actors, such as the policy implementing agency (Ministry of Agriculture, Animal Industry and Fisheries [MAAIF]), research (NARO and CGIAR Centers), training institution (Makerere University), donors, extension agents and farmers, were involved. These actors played different roles at this stage, mainly related to demand articulation, visioning and network building.

Setting the research agenda started with identifying problems in banana production. Interviews with researchers indicates that this followed reports on the outbreak of banana pests and diseases in central Uganda. These reports led researchers from NARO to engage with various actors, including MAAIF and Makerere University supported by donors such as the Rockefeller Foundation, to conduct a field diagnostic study that established the extent of damage to the crop. Farmers and extension staff were involved in guiding the assessment as respondents and informants, respectively. Conducting a diagnostic study at farm level and the approach used characterises a change whereby more stakeholders, especially farmers, were involved to inform the planning of a scientific process. Corroboratively, key informant interviews revealed that, overtime, there has been a change and effort to involve different actors in the identification of research needs, as explained by one of the actors:

Research needs are currently jointly identified during our interaction with farmers. In the past, we used to get technologies from research and we were required to implement without question. But, things have changed. There is more participation whereby farmers, extension staff and researchers meet to jointly identify constraints which are disaggregated into those to be addressed by research and extension. The constraints that require research-based solutions are forwarded to researchers to handle. (Agricultural extension officer, Mukono District, 12/02/2015)

Having identified the problems, it was necessary to define and prioritize the potential interventions. Actors, such as policy makers, researchers, training institutions and donors were involved in defining the intervention strategy. However, findings indicate that the need to breed resistant banana varieties was opted for by mainly breeders from research since new varieties were viewed to be the most cost-effective way of addressing the predominant constraints;

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**Figure 2.** Venn diagram showing the level of actor involvement in key activities of setting the research agenda.
Given the high cost of fungicides, their unavailability to smallholder farmers, and the recurring problem with fungicide resistance, it was clear that genetic resistance to black Sigatoka would be most feasible option. If resistant and acceptable cultivars are available, they would provide the best solution to this problem. (Breeder, 16/04/2015)

Although invisible, donors had interest in the selected strategy of breeding new varieties since this presented a tangible output as a measure of success. Actors such as farmers and extension agents were not visible during the process of defining the intervention.

To effectively breed new cultivars, breeders at NARO needed to identify partners with whom they could collaborate for the success of the process. It was found out from the interviews that when the breeding strategy was agreed upon, researchers from NARO, as lead actors in the BTD process, selectively identified and engaged other actors that were perceived to play an important role in the technology generation process. CGIAR centres (International Institute of Tropical Agriculture [IITA] and Bioversity International) were identified as actors to collaborate with in the process of developing new HBVs.

Although results show that different actors were involved in setting the research agenda, there were variations in the extent of their involvement (Figure 1). Actors, such as the national research entity, were present in all the activities while farmers and extension agents were only involved in identifying the problem at this stage. Other actors, such as policy makers, training institutions and CGIAR centres were involved in at least two activities of this stage. Involvement of actors was largely determined by the nature of activity and how each actor was perceived to contribute to that activity. Farmers and extension agents mentioned that usually, the focus of the needs assessment and intervention strategy are essentially pre-determined by researchers. As actors in the process, they are simply consulted for opinions rather than being rigorously involved in priority setting for a jointly shared research agenda. Also, it was evident during the interviews that only researchers were in a relatively better position to describe the planning phase of the BTD process, compared to other actors. Exclusion of such actors in decision-making at the prioritising and strategizing phase has critical implications on successful technology development, acceptability and uptake. It was necessary to collectively harmonize interests, preferences and needs of all actors at the priority setting stage since this allows for demand articulation and a shared vision for all the actors. This deliberate effort would mean that all actors are involved in and are informed of the actions taken in the entire process of setting the research agenda, which would position them in the unification cell for actors’ involvement (Figure 2). Farmers, as key actors, need to play a more inclusive role in the collective identification of interventions on which researchers can build for the effectiveness of the research process and relevance of the breeding output. Further, more attention could have been placed on analysis of trait preferences for men and women end-users as a guide to breeding of new varieties. Such a step is critical to clearly identify and define targeted users as well as their diverse needs and preferences for varietal traits so as to guide breeding of varieties that include the preferred traits for both genders (Christinck, Weltzien, Rattunde, & Ashby, 2017).

3.2. Stage 2: Breeding new HBVs

The material making of the matooke hybrids followed a scientific approach that involved germplasm collection and characterization of breeding materials, cross pollination of the female varieties and laboratory screening. Therefore, most of the activities carried out at this stage were based on the technical aspects of plant breeding. Since this is largely a scientific process, the analysis aimed to identify how these technical activities were implemented, particularly the methods used, the actors involved and how they contributed to the decisions in the process.

Findings from interviews with researchers indicate that most of the actors at this stage were technical actors, mainly from the education and research domain. National breeders from NARO, in collaboration with breeders from IITA, identified the breeding approach and materials. The conventional cross-breeding approach was considered to be the most appropriate given the nature of the crop.
Breeders also identified sources of resistance, and Calcutta4—a wild resistant banana cultivar—was obtained by Bioversity international from the International Transit Centre (ITC), Belgium for crossing with the farmers’ preferred local cultivars. Researchers from Makerere University were involved in the process of characterising the matooke landraces since they had the necessary expertise.

Discussion with banana breeders indicate that although conventional cross-breeding was considered the most appropriate approach at that time, it is slow, costly and less participatory. This corresponds with the technical view of Ortiz (2011) on conventional banana and plantain breeding. Conventional cross breeding of banana involves the transfer of pollen from resistant fertile diploid male plants to the female flowers of triploid clones with female fertility, to obtain resistant tetraploid hybrids. This approach is complicated by the long duration of 18 months for the crop to establish from seed to seed. The complex banana genetics, low genetic variability, polyploidy and the low levels of female and/or male fertility in most widely-grown triploid clones once made banana cross-breeding an almost impossible venture (Pillay, Hartman, & Tenkouano, 2002; Rowe, 1984). These challenges made the probability of obtaining an acceptable product uncertain at the initial stages of BTD. This approach also restricted the involvement of actors, such as farmers, extension agents, the seed sector, and the integration of their views in the early stages of the breeding process as compared to other approaches, like participatory plant breeding, which have proved to be effective in engaging different actors in the breeding process (Assefa et al., 2014; Ceccarelli, 2015; Witcombe et al., 2005). Additionally, the use of a wild banana rather than a matooke parent was appropriate for breeding purposes but could explain why the hybrids failed to meet the attributes of the matooke consumers. This relates to the findings of Ceccarelli et al. (2000) and Witcombe et al. (2005) that use of germplasm that can best meet the needs of target clients is important in breeding programmes and it enhances acceptance. Breeders’ own recommendations indicated the need to continuously identify and embrace participatory approaches and techniques at the breeding stage for bananas. This concur with the suggestion by Ortiz (2011). Approaches that allow for quick selection and involvement of relevant actors at early stages of breeding ultimately enhance the quality of research outputs thereby contributing to higher levels of uptake of selected lines.

### 3.3. Stage 3: Trait evaluation and selection of new HBVs

The promising lines were tested, evaluated and selected in Early Evaluation Trials (EET), Preliminary Yield Trials (PYT) and Advanced Yield Trials (AYT). The aim of the different stages of evaluation was to identify promising hybrids that could be advanced for cultivar release. From over 1,000 lines at the crossing stage, 28 were selected and tested at PYT and 18 at AYT (Figure 3). The 18 conventionally bred hybrid lines selected at AYT were advanced to multi-locational and On-Farm Trials (OFT) for further evaluation and selection in comparison to a local check - Mbwazirume. The multi-locational trials were established at selected ZARDIs while on-farm trials were established on 18 farmer’s fields.
in Nakaseke District. Sensory evaluations were also done at PYT, AYT and on-farm to assess consumer acceptance and preferences. At PYT, the sensory evaluations were done at a NARO institute (Kawanda) by a panel comprised of mainly staff and consumers from the surrounding areas, while at AYT the evaluations were done with farmer research groups in Nakaseke and Wakiso Districts.

The evaluation and selection of lines at EET and PYT was mainly done by breeders at NARO and IITA, basing on criteria that largely focused technical production and agronomic related traits such as plant growth, yield (measured by bunch size and weight) and resistance as it is for most plant breeding programmes. At this stage, private tissue culture laboratory operators/entrepreneurs were contracted to multiply the planting materials that were distributed to host farmers for the on-farm trials. Selections of lines during the on-farm trials was done by farmers in collaboration with researchers. Four lines (M2, M9, M14 and M17) were selected as the most promising hybrids among which M9 and M2 emerged as the best performing and were advanced for release. The selected matooke hybrids performed better than the local check in terms of yield, plant growth related attributes and resistance to diseases (Table 1). However, when overall acceptability and preference for culinary attributes of food appearance, taste, flavour and texture were scored using a structured six point hedonic scale that ranged from one for extreme disapproval to six for extreme approval (Ssali et al., 2010), the local check was scored highest in all these quality attributes (Figure 4).

Involving farming communities in the evaluation and selection process is a better way of selecting new crop varieties and this is meant to guide choice of the most acceptable hybrids. However, findings at this stage allude to the fact that the breeders prioritized mainly technical attributes of the varieties during the evaluation and selection of new varieties. The hybrids were evaluated for

| Attributes                                      | Local cultivar (Mbwazirume) | M2   | M9   | M14  | M17  |
|------------------------------------------------|------------------------------|------|------|------|------|
| Mean bunch Weight (Kgs)                        | 15.5                         | 23.2 | 21.3 | 20.1 | 22.4 |
| Maturity period (number of days from planting to flowering) | 452                          | 374  | 447  | 408  | 392  |
| Number of days to fruit maturity               | 112                          | 142  | 133  | 132  | 132  |
| Black sigatoka resistance (index of non-spotted leaf) | 51.2                         | 84.1 | 74.9 | 82.6 | 86.8 |
| Number of leaves at harvest                    | 1.2                          | 5.6  | 4.3  | 4.5  | 4.4  |
| Plant height at flowering                      | 321                          | 309  | 340  | 292  | 315  |

Source: Authors own analysis based on data from an article by Ssali et al. (2010).
disease and pest resistance, yield-related traits and plant growth related traits since these were perceived by breeders to be the most important criteria used by farmers to select cultivars for growing. The intrinsic quality attributes related to socio-cultural and gender-specific preferences were given limited consideration during the selection of hybrids for advancement and release. This corroborates with other studies (Ceccarelli, 2015; Mgumia, Mattee, & Kundi, 2015) which report that most researchers are largely accustomed to indicators associated with productivity potential, ignoring a wide body of literature showing that yield is not often the main driver of uptake. Such quantitative indicators undermine the value and use of qualitative indicators in assessing new technologies. Indicators related to the intrinsic quality attributes and socio-cultural values, such as food taste, texture, flavour and colour which are valued by farmers, particularly in the central region for whom the new hybrids mainly targeted, were necessary for enhancing uptake. Failure to integrate and prioritize such attributes in the development and selection of matooke hybrids may probably explain the low uptake of new HBVs. There was a need to consider the social attachment that the farming communities have about matooke varieties because matooke is the staple food crop in Central Uganda (Nowakunda et al., 2015). To these farmers, food taste, flavour, texture and appearance (colour) are among the most key considerations. Farmers in the central region prefer matooke that takes long to harden when served (with high heat retention capacity) and with a deep yellow colour;

The hybrid varieties yield well and are tolerant to diseases, pests and drought but the taste is not good. The colour of cooked food is not deep yellow like our local matooke types. It also hardens very fast even after steaming for more than six hours. One needs to eat this matooke hybrid while on the cooking stove or immediately after taking it off. (Female farmer, Nakaseke District, 2/05/2015)

Results of the discussions with breeders indicate that the process of breeding bananas was much longer than it is for most of the other crops. Researchers were therefore under pressure from donors to release and deliver matooke hybrids to farmers. This complicated the selection process as the researcher’s interest was in fulfilling its mandate of developing new varieties and that of the donors’ need for a tangible output from the process while addressing the farmers need for a new variety with desired attributes. Ultimately, this caused a mismatch in the criteria for varietal attribute selection between researchers and end-users (farmers and consumers). To the farmers, it was not just about disease and pest resistance but also to what extent the new varieties met the use and consumption attributes inherently present in their local cultivars. Glenna, Jussaume, and Dawson (2011) while assessing how farmers matter in shaping agricultural technologies observed similar findings that end-users may have an interest in a technology for reasons other than what the technology developers (plant breeders) intended.

The differing interests and influence of actors, such as donors and researchers on the actions and decisions at this stage compromised the selection criteria. This made it difficult for the researchers to fully integrate farmers’ preferences and feedback on the social and quality attributes in a bid to release new varieties. The failure to integrate farmers’ feedback on desired attributes could offer an explanation for the observed low level of uptake of matooke hybrids. Other related studies (Feder, Just, & Zilberman, 1985; Smale, 2007) post similar findings that adoption of a new technology by smallholder farmers largely depends on the extent to which the new technology meets the underlying social conditions and intrinsic attributes. Farmers’ dissatisfaction with attributes of a new technology is an important disincentive to the adoption of most agricultural technologies. Research needs to be aware of end-users’ preferences and their potential constraints to use of new technologies since this ultimately determines acceptability of new technologies. As Douthwaite et al. (2017) note, it is imperative that technology developers shift from being outside “knowers” to “enablers”. That way, researchers will be able to facilitate rather than control the selection process. This will enable end-users to play a key role in the evaluation and selection of new varieties so that only those varieties that meet their needs and preferences are considered for release.
3.4. Stage 4: Variety naming, release and registration of Matooke hybrids

At this stage, studies were conducted in support of the requirement for Distinctiveness, Uniformity and Stability (DUS) by MAAIF for any new variety. Breeders at the NBRP compiled the required data and applied for release and inclusion of matooke hybrids on the national cultivar list. During breeding, the hybrid lines were represented by different cultivar numbers and later, the “M” initial was coined as a label for Matooke so that farmers would easily relate with the new cultivars. In 2010, variety M9 which emerged as the best candidate at the evaluation stage was advanced for release. The variety was observed to be disease resistant and tolerant to pests and drought which increases plantation longevity. As a result, farmers in the location where the variety was tested and evaluated on-farm named it “Kiwangazizi” in the local language (Luganda) which literally means “long lasting”. To them, this name was a good descriptor of a variety that addresses the major challenges that affected banana production. The variety (M9) was released later in 2010 as “KABANA 6H” by the national variety release committee of MAAIF.

Complexity at this stage mainly resulted from the criteria used to file the varieties for release, the label (name) given to the emerging matooke hybrids and extent of actor involvement. The criteria for release mainly focused on technical attributes of the new cultivars, while the rigor for farmers’ preferred attributes diminished. Although a name can be regarded as just a label, information from the FGDs with farmers indicate that a name of a new variety has an effect on its use. Farmers’ naming criteria were associated with variety attributes and this differed from the NARO nomenclature. However, the varieties were named, released and registered according to the NARO criteria. The use of a different label from what farmers think is appropriate implies that farmers, as actors in the development process, are passive participants with limited influence on how decisions are made in the process. It was observed during the FGDs that farmers do not seem to understand the naming process of new varieties, making them associate even the most suitable varieties with genetically modified (GM) technologies. Naming the varieties according to researchers’ criteria delinks with farmers’ known attributes which also de-orient their attitude towards new crop attributes and their perceived benefits. The official variety names tend to be complex for end-users to comprehend. This, coupled with limited awareness about the meaning of the names, impacts negatively on farmers’ perceptions and attitudes about new crop varieties from research, thereby limiting their “ownership” and eventual use despite having participated in the selection process. Also, extension agents, as key actors in the intermediary domain, were not involved in the release process; yet they are critical to the promotion and diffusion of new technologies. Research needs to recognize the role of farmers and extension agents in the research process, and farmers should be given a chance to participate in the naming and release processes of new varieties. Release of the varieties should be proceeded by a strategy that seeks to widely disseminate information about HBVs to stimulate and catalyze uptake. Such a communication strategy should focus on constant provision of information customized to the different actors such as farmers, consumers, private entrepreneurs and traders so as to change their attitudes and misconceptions about HBVs.

3.5. Stage 5: Promotion and commercialisation of new HBVs

Key activities at this stage included on-farm demonstrations, field days, training and distribution of plantlets. These were largely implemented by researchers, extension and farmers with donor support. During the interviews and FGDs, actors in different categories were asked to rank the weakest node in the BTD process. The majority (95%) of the responses across actors indicated that promotion and commercialisation was the weakest link. This was mainly attributed to limited in-built strategies for creating awareness and interest among users, as well as minimal involvement of other actors in the planning and implementation of promotional activities.

The results indicate inadequacies in the level of actor involvement in promotion and dissemination of matooke hybrids. While actors, such as local leaders, NGOs and media, play an important role in popularising new technologies, they were rarely involved. Research continued to take a leading role in the promotion of new HBVs through distribution of planting materials on a free-of-charge basis. Despite the emergence of private companies dealing in tissue culture materials for bananas,
research was reported to still be at the forefront of multiplication of matooke hybrids for dissemination. The NBRP continues to contract tissue culture laboratories to multiply planting materials on a commercial basis for free distribution to end-users. Literature shows that activities that aim at facilitating diffusion of new technological knowledge are an essential function of any innovation system (Hekkert et al., 2007; Johnson, 2001). Although other studies have indicated greater success and impact where the R&D team continued to champion the technology (Douthwaite & Gummert, 2010), the findings herein are an indication of what Mgumia et al. (2015) characterise as partially successful innovations. Such innovations are mainly multiplied and disseminated in informal and unsustainable project-based interventions that target a limited number of users over a short time-span.

The leadership of research in promoting new HBVs could be attributed to limited interest among entrepreneurs, mainly private tissue culture laboratory entrepreneurs, to invest in the multiplication and commercialisation of matooke hybrids. The low interest is attributable to low demand for hybrid bananas and their (private tissue culture laboratory entrepreneurs) diminished involvement in the process leading to new HBVs. In line with Wieczorek and Hekkert (2012), future technological development processes in banana sub-sector need to involve actors that perform entrepreneurial activities from the outset of the innovation process. This will trigger their interest in the new technology and probably contribute to their ability to invest in multiplication and commercialisation of new varieties. From their perspective, key informants (mainly research, extension and farmers) suggested that research needs to proactively engage and collaborate with other agencies that brand and promote research outputs in a way that attracts end-users. Further, promotion needs to be a well-planned process with clear progression activities if it is to achieve the intended results. Therefore, promotion should not be looked at as an end activity; instead there should be in-built mechanisms and activities that engage the necessary actors from the onset of a breeding process.

4. Reflections on the BTD process

R&D organisations generally approve that yield-enhancing technologies, particularly new crop varieties, are vital to increasing agricultural productivity. Results showed that new HBVs have been developed, released and promoted among users to boost banana production. However, appreciation of these varieties among end-users particularly farmers and the private sector remain a challenge. Insights from the findings and literature are used as a basis for reflections regarding the process and implications for generation of new technologies with enhanced potential for uptake. These insights demonstrate the complexities and gaps in the BTD process that ultimately impact the development, acceptance, use and diffusion of new HBVs.

Results of this study have shown that the new HBVs resulted from a five-stage process that followed the conventional scientific breeding approach. Performance of the new HBVs was largely measured by yield and resistance to pests and diseases as key criteria in the selection process, which could also explain why sensory analysis studies were introduced later in the process and its outcome not fully integrated. The focus on mainly technical aspects coupled with the long breeding time affected integration of farmers’ preferred quality attributes related to socio-cultural and gender-differentiated preferences that emerged during evaluation of new HBVs. Two possible explanations could be advanced for this result. First, there was limited gender integration in the process of developing new HBVs across the stages. This could have resulted from the failure to identify and define the gender dimensions of the problem that was to be addressed by the BTD process. Quality attributes are critical to matooke growers, and are important factors for inducing market demand and use particularly in central Uganda. Secondly, the national breeders supposedly knew the suitable cultivars and the necessary traits while the international level breeders had networks beyond technical knowledge that complemented the research efforts. Other categories of researchers, such as social scientists and zonal level scientists who are critical for assessing the end-users and zonal specific preferences respectively, were not fully involved at most of the stages. Although the research system in Uganda has emphasised multi and interdisciplinary research teams overtime, this seems not to be happening in reality or it happens later in the research process. Key informants argued that different disciplines are important in the entire process and their involvement from the onset to
assess how the technologies being developed meet the existing specific needs and preferences has the potential to enhance adoption of these technologies.

The results of the study indicate that technology attributes remain an important factor in influencing uptake of new HBVs. The study provides empirical insights into the need to integrate both technical (qualitative) and social (qualitative) attributes while developing new banana varieties. This implies that both technical and social attributes should be prioritized in the selection of new HBVs to advance for release. This corroborates with other studies particularly on banana (Akankwasa et al., 2013; Edmeades et al., 2007; Kikulwe, Birol, Wesseler, & Falck-Zepeda, 2011) that identified adoption of new banana varieties to be determined by both production and consumption attributes. Thus, it is fitting to target to engage end-users (particularly farmers and private sector) along the banana value chain earlier in the technological development process to prioritise and support generation of technologies aligned to their needs and preferences. Such an arrangement would stretch the breeding process but guarantee high levels of acceptability of the breeding output. This calls for more participatory approaches and techniques in crop variety improvement and development programmes. Breeders’ recommendations indicated the need to develop methods that can enable them [breeders] to select for various traits at once, instead of multiple evaluations of lines for various attributes which slows the process.

From the AIS perspective, identification and involvement of multiple actors is central to the performance of any innovation process typified by the BTD process in this study. The actors support the innovation process by performing innovation activities (functions), which contribute to the goal of the innovation system. This study has demonstrated that although various actors were involved in the BTD process, variations in the level of their involvement and roles performed exist. The findings further indicate absence of critical actors at certain stages and across the BTD process. Within the stages, there was minimum involvement of the seed sector, extension and certain categories of scientists, while across the BTD process, local leaders, agro-processors, financial institutions and media were missing actors yet these play a critical role in stimulating demand. The absence or diminished involvement of necessary actors at different stages of the process shows shortfalls in the BTD process and could be a possible loophole in enhancing uptake of new HBVs. This concurs with Senyolo, Long, Blok, and Omta (2017) who noted that failure to adequately involve the end users (especially farmers) during the development phase can lead to non-adoption of new technologies. Further, Woolthuis, Lankhuizen, and Gilsing, 2005 (cited by Wieczorek & Hekkert, 2012) indicate that absence of certain actors can lead to systemic problems which may hinder the development and functioning of an innovation system. This paper emphasises the need to reorient technology development processes such that actors are brought on board earlier in the process with clearly defined roles. Adequate involvement of diverse actors in technology development is critical for adequate incubation of new technologies and serves as a key motivator for uptake.

As discussed, involvement of actors varied from stage to stage, depending on their perceived roles and usefulness. However, it emerges from the results that researchers at the national level, mainly breeders, took the lead for most of the important activities and decisions throughout the entire process with evolving roles. Although the leading role of research could be attributed to their mandate and technical expertise to guide the process, it barricaded other actors’ involvement, performance of their functions and integration of their ideas in the innovation process. This limits optimal support to enhance development and uptake of new technologies. It also indicates that latent use of a linear, top-down approach is still inherent in research systems which negatively impacts uptake of outputs from ATD process.

5. Conclusions and recommendations

In this paper, the process of developing agricultural technologies was analysed to gain an understanding of how this process affects technology uptake from the AIS perspective. This paper provides insights into the processes, activities, and actors, their roles and extent of involvement in the development of new HBVs and how this accounts for their uptake. The paper contributes to the existing literature by providing an integrated view of agricultural technology uptake and its inducing factors in the ATD context.
Overall, the study concludes that leadership in variety development in the banana sub-sector is being coordinated by NARO and other research-orient actors. Such as, the process of developing new varieties is largely controlled by agricultural research institutions with limited involvement of other actors such as farmers, private sector actors and extension staff across the stages. Additionally, technical attributes remain the key drivers in selection of HBVs in the early stages while consideration for social attributes happens in the later stages. This affects integration of social and quality related attributes which ultimately impacts on acceptance and use of new HBVs. The study thus proposes an integrated approach that provides a holistic framework with a social perspective for ATD and optimizing uptake. Based on the AIS, new technologies should be a result of an iterative process that fosters feedback while allowing for actor involvement in prioritization at different stages of the process. Such a process needs to take into account both technical and social aspects as well as the needs and traits preferences of both men and women end-users.

From the practitioner’s perspective, research needs to reorient ATD processes to be a rigorous but flexible process that identifies and actively engages the necessary actors while integrating their knowledge, skills and capabilities and recognising their interdependence for a better functioning of the system. Further, researchers should re-orient their role in the process to be more responsive to the needs of the innovation system, particularly end-users if uptake is to be improved. In particular, breeders need to appreciate the complementary role of social science in the scientific research process. This will require breeders to re-define their role as “champion actors” in the technology generation process. From how they have been described and classified overtime, breeders need to change and play more of a catalyst role in the process, allowing for other actors to play different roles that can stimulate and sustain use of the new technologies. Additionally, research needs to redefine the indicators for measuring research outputs and successful technologies. Rather than focusing on the number of varieties released, this study recommends that uptake, should be prioritised as a measure of research success.

Farmers’ efforts and participation in technology development interventions should also be rewarded by involving them in naming the varieties in a way that is familiar to them as target end-users, to foster their “ownership” of the new varieties. This would require a blend between farmers’ preferred and technical attributes, implying redefining trait evaluation and selection criteria. Since the varieties which farmers may choose to grow may be different from the breeders’ choice, there is need to integrate farmers’ preferences differentiated by gender if breeding programmes are to be more relevant to the needs of men and women end-users. Additionally, practitioners need to be aware that a “blanket” approach is not as effective as a “tailor” approach to the naming and release of new varieties. A tailored approach takes into account the differences between communities, implying that release of tailor-made varieties targeting specific regions would require decentralised release processes that take place in the actual locations with the active involvement of key actors and stakeholders, such as extension, local and political leaders, among others. This will accelerate diffusion and also serve as a promotion strategy for enhancing technology use and diffusion.

From a policy perspective, the study highlights the need for effective partnerships and collaborations in ATD and dissemination. This could be achieved by establishing multi-actor platforms and strengthening the existing private-public partnerships in technology development and promotion. NARS needs to streamline the engagement of actors in the ATD process while empowering them to support and sustain the new technologies. It is also important that the National Agricultural Research Institutes (NARIIs) streamline their engagement with Zonal Agricultural Research and Development Institutes (ZARDIs) in research processes, since these were established to adapt and disseminate research and technology outputs across the different agro-ecological zones. Stronger collaboration between the NARIIs and ZARDIs will not only tap into the potential of ZARDIs to contribute to wider impact but will also serve as a mentoring process for zonal level scientists. Such collective and collaborative arrangements that support efficient and effective exchange of information will go a long way to accelerate the proliferation and uptake of new varieties.
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