Perceptions on the Challenges of Banana Cultivation and Bio-based Technology Use Among Malaysian Smallholder Farmers

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ABSTRACT

Bananas are one of the most commonly grown fruit crops in Malaysia, but local production has declined in recent years. Through site visits and interviews with 74 smallholder banana farmers, this study sought to know the current situation of the local smallholder banana industry, the challenges faced in commercial banana cultivation, and the use of bio-based technologies to address the challenges. The farmers cited increasing production costs, pests and diseases, and yield uncertainties as major challenges to their plantations' survival. While they have been using farming techniques, including bio-based technologies, to improve fruit yield, the farmers perceived the current technologies as inadequate in mitigating the impacts of frequent disease outbreaks. The interviews also reveal farmers' misconceptions on the nature of tissue culture technology, reflecting their poor understanding of how tissue culture works, thus, putting banana farms at risk. Overall, this study's direct engagements with banana farmers show that correct information and access to technology are a rare privilege for smallholders. Therefore, coordinated efforts to substantially increase support for smallholder farmers is paramount.

Keywords: barriers, technological adoption, impact evaluation, sustainable agriculture

JEL codes: Q12, Q16

INTRODUCTION

Banana, a vegetatively propagated fruit crop, has a high demand because of its unique flavor, all–year–round harvest, and nutritional values. The banana industry is highly fragmented; its international trade is largely controlled by multinational companies such as Chiquita, Dole, and Del Monte, followed by medium- and large-scale commercial plantations, then smallholder farmers (FAO 2014). Although the industry is an important and widely traded business, banana plantations in Malaysia are plagued by various issues, especially disease outbreaks (Zulperi and Sijam 2014; Teng et al. 2016). These problems are prevalent, particularly among smallholders who are resource-poor, unorganized, have limited access to information, and lack awareness of technologies and appropriate plantation management practices (Kayat et al. 2016). Nonetheless, successful projects such as the deployment of banana tissue culture technology for smallholders in India (APAARI 2019) and Kenya (Kikulwe et al. 2012; Bandewar et al. 2017) and the adoption of an artificial intelligence (AI)–based mobile app for disease detection in Uganda, Congo, and India (Selvaraj et al. 2019) demonstrate that such technologies can help smallholder farmers improve farming practices and increase yields.

This study sought to understand the challenges faced by smallholder banana farmers in Malaysia and their use of bio-based technologies to address these challenges. Its results are expected to be useful for developing agricultural policies that match the needs of targeted smallholders to improve Malaysia's banana industry. As a first step, the study analyzed the current landscape of bio–based technology use among smallholder banana farmers in Malaysia, guided by the following questions:

1. What are the perceived challenges faced by smallholder banana farmers in Malaysia?
2. How do smallholder banana farmers use commercially available innovations, specifically bio-based technologies, to overcome the challenges they face?
3. How might new technological developments, such as bio-based technology, better address the challenges faced by banana plantations in Malaysia?

METHODOLOGY

Research Participants' Selection

This study involved smallholder banana farmers in Malaysia, a country in Southeast Asia, which is the center of origin of edible bananas and plantains (Jamaluddin 1999). The banana industry is important to Malaysia as it accounts for 26.4 percent of the gross value of the country's fruit crop output, according to the 2017 Malaysia Fruit Crops Statistics (Department of Agriculture Malaysia 2017). Bananas are grown in estates (more than 40.5 ha), midsize commercial plantations (4–40.5 ha), and smallholder farms (less than 4 ha) for domestic consumption and for international markets, mainly in neighboring countries such as Singapore (Khazanah Research Institute 2019). Based on the above definitions, the banana farmers who participated in this research have smallholder farms.

Research Design

The study design is cross-sectional. The mixed methods approach was carried out between December 2018 and June 2019. It involved a self-administered structured questionnaire survey and qualitative semi-structured interviews. Data were collected to have an overall picture of smallholder banana production in Malaysia and to capture farmers' opinions on the challenges confronting banana farming, the technologies used to address the challenges, and the benefits gained from adopting such technologies. As the respondents can read and write in Malay (the national language), the questionnaire and interview questions were written in Malay. The ethics approval for this

study (UM.TNC2/UMREC – 440) was granted by the Human Research Ethics Committee of the University of Malaya.

Structured Survey Questionnaire

The questionnaire was validated by an extensive review of the literature, including previously established questionnaires (Muyanga 2009; Kabunga et al. 2014), and by consulting local banana researchers and agricultural officers. The six-page, self-administered questionnaire took 20 minutes to complete. It was pre-tested on seven farmers. Consequently, certain questions were reworded to improve clarity.

The final version of the questionnaire consists of three sections. Section 1 asks for information on the respondent's background (four items). Section 2 delves into plantation characteristics, particularly geographical location and age of banana farm; hectarage and production yield in 2017 and 2018; banana cultivars planted; proportion of cultivation costs; incidence of disease outbreaks, pest attacks, and flooding between 2007 and 2018; and use, if any, of bio-based technologies. In addition, this section asks about problems related to banana cultivation: "Please state if there are any other problems that you have encountered when being involved in banana plantation." It also requests the respondents to rate the relevance of the problems on a 10-point scale and to describe the incidences of pests, diseases, and flooding in the past 10 years, as well as the damage these have caused. Section 3 covers the marketing aspect, particularly selling price and market segmentation for cultivated bananas in 2018 and 2019. It particularly asks about the sales amount of each cultivar and their respective selling prices at the farm or at nearby market and distribution centers.

Semi-Structured Interview

After completing the self-administered survey, the farmer respondents had individual 30-minute interviews with the field interviewer. They were asked about challenges related to their plantations, their awareness of available bio-based technologies, the importance of developing new technologies such as biotechnology tools to address banana farming challenges, and the role of government in providing access to technology.

Data collection

Prior to the site visits and survey administration, a national database of 1,957 banana farmers was created for this study, based on information provided by the Department of Agriculture (DOA) of Malaysia. A sizeable number of farmers had to be omitted, however, as they were not smallholders (56 farmers, 2.9%); not reachable or no longer active (1,819 farmers, 93%); or still active but not willing to participate in this study (82 farmers, 4.1%). A total of 74 farmers participated in the survey, representing 47 percent of active smallholder banana farmers on record. During the site visits, the field interviewer distributed the survey questionnaires, which were prefaced with a letter from the head of the project encouraging the respondents' participation. The field interviewer also verbally explained how to complete the survey. With the respondents' consent, the interviews were video recorded.

Data analysis

All survey responses were recorded using Microsoft Office Excel Spreadsheet Software for Mac (version 16.25). The weight of each response related to challenges of banana plantations was reviewed twice; the challenges were later coded according to the items.

Data collection and preliminary data analysis were done concurrently, which is a feature of qualitative analysis (Miles et al. 2014; Corbin and Strauss 2008). A transcript file for each respondent was created immediately after the interview. The file contained evaluation notes of the interview session, a summary of the interview, and transcription of the audio recording. This allowed the field researcher to be familiar with the existing data and generate strategies to collect new and better data in subsequent interviews.

RESULTS AND DISCUSSIONS

An Overview of Banana Smallholder Farmers, Production, and Trades

We analyzed the current landscape of banana cultivation among smallholders based on the survey and interview responses of 74 banana farmers. Their farms are in nine states in Malaysia: Johor (13 respondents), Kedah (16), Kelantan (11), Negeri Sembilan (6), Pahang (3), Perak (3), Pulau Pinang (1), Selangor (8), and Terengganu (4). Most of the respondents have individual farming households, while those in Kelantan work in groups. The majority are male (71 farmers, 96%) and only three (4%) are female. The respondents tend to be relatively elderly: 62 percent are above 50 years old.

In terms of the channels used to obtain information on banana cultivation and management practices, the respondents cited farmer exchange visits (n=62), consultations with government agencies and nongovernmental organizations (NGOs) (n=34), and printed and electronic media (n=24).

This study covered a total of about 130 ha of banana landholdings. Almost half (42%) of the respondents have less than 1 ha farms; the farm sizes of the other surveyed farmers are 1.01–2.00 ha (27%), 2.01–3.00 ha (13.5%), and 3.01–4.00 ha (17.5%).

Perceived challenges of banana cultivation

We extracted the list of challenges from the farmers' responses to the open-ended questions in the survey and interviews. Table 1 summarizes the farmers' opinions using a three-part scale: very relevant (++), relevant (+), and less relevant (-).

Typical of many smallholders, the respondents generally have limited financial capital to establish and manage their plantations. The majority often pointed out that the cost incurred is high; hence, without external financial assistance, it would be difficult for them to sustain their farms. The costs include capital inputs (e.g., land, irrigation system, equipment/machineries, four-wheel-drive tractors, and electrical fences) and operating expenses (e.g., labor, utilities, fertilizers, pesticides/herbicides, hormones, and planting materials).

Table 1. Challenges related to banana cultivation

Challenge	Relevance/Importance
High cultivation cost	++
Susceptibility to diseases	++
Crop theft	++
Yield uncertainties	++
Sale price risks	++
Flood	+
Susceptibility to pests	+
Wild animal attacks	+
Soil fertility	+
Diseased seeds/unhealthy planting material	+
Drought stress	-
Labor constraint	-
Limited access to financial aid	-

Note: Farmers' opinions are tabulated using a three-part scale: very relevant (++), relevant (+), and less relevant (-). The three-part scale was derived based on the weight of the item recorded in the interview and its frequency of mention in the interviews. However, it should be noted that this assignment is qualitative and used to illustrate only the descriptive aspect of the results.

Labor is the highest of all cost factors, accounting for 25–60 percent of the total cost.

The respondents frequently cited the role of government agencies in providing financial assistance to smallholders. They also expressed concern over the low selling price for their harvest and the minimal profits they gain, as opposed to large commercial plantations, which they perceived to earn enough profits and, thus, can sustain their operations. The farmers believed that government interventions, such as loans and free expert advice, are important to help them access the latest technologies at a more affordable price.

Another important issue is the outbreak and spread of diseases. Almost 60 percent of the respondents said their farms had been infected at least once in the past five years by either *Fusarium*, Moko, or Sigatoka diseases. Moreover, as far as they are concerned, there are no effective chemical and biological measures available to treat *Fusarium* and Moko diseases. Thus, to manage their diseased plantations their only recourse was to adopt measures according to Good Agricultural Practices, as outlined by Malaysia's Department of Agriculture (Department of Agriculture Malaysia 2009). That is, once the farmers detected the disease symptoms in their plantation, they would destroy the infected banana plants, disinfect the land, and avoid replanting for a specified time period. As a result, they experienced significant yield and income losses. As explained by a respondent (farmer 23, five years of farming experience): "As usual, the problem with banana plantation is diseases. Every time I grow bananas, there will always be plants infected by diseases. When that happens, I remove the infected plants and replace them with others."

Technology use and benefits gained

The farmers were found to have a good understanding, knowledge, and awareness of techniques that are beneficial for banana cultivation. In all the interviews, all respondents indicated having used herbicides, fruit protection techniques (e.g., fruit bunch cover), and bio-based technologies to achieve high yields. However, not all farmers have adopted bio-based technologies for banana cultivation. Of the available bio-based technologies, tissue culture (TC) plantlets have been used by 40 percent of the surveyed farmers (n=28), rooting booster hormones by 30 percent (n=22), effective microorganisms by 22 percent (n=16), and organic fertilizers by 14 percent (n=10). The non-TC adopters expressed concerns about handling of TC plantlets, which are delicate at their early stages, thus, their reason for not favoring its use as planting materials. The cost of TC seedlings, which is higher than the price of field-grown suckers, logistic issues related to minimum orders of TC seedlings, and lack of market access to sell the harvest when fruiting is simultaneous are also key reasons for non–adoption of TC plantlets among banana farmers.

Mostly, TC adopters owned or rented a plantation of more than 2.01 ha. Typically, they are more experienced in the industry and well connected with other banana farmers, relevant government agencies, and NGOs. According to the farmers, they observed that bananas grown from TC plantlets grow uniformly, can be harvested more rapidly than those grown from conventional suckers, and are of good quality. Because of these advantages, the farmers see the use of TC plantlets as a worthwhile investment, even if this would mean a considerable increase in the overall production cost.

"I have used tissue culture technology for quite some time. The benefit is, of course, the fruits are all uniform. However, I noticed that the first batch of planted banana is Moko disease resistant, while half of the second batch is infected by the disease (farmer 18, nineteen years of farming experience)."

"Tissue culture is more expensive than suckers, but the good aspect about banana tissue culture is all plants will produce fruit quicker (farmer 23, five years of farming experience)."

These views of the farmers concur with the findings of a study carried out in Africa by Wambugu et al. (2001). Like the African farmers, TC adopters in Malaysia gained benefits, such as more efficient coordination of production, harvesting, and marketing.

Improvements to technology development and farming practice

This study confirms that banana cultivation challenges are heterogeneous among Malaysian smallholder banana farmers. These farmers use an array of bio-based technologies, including tissue culture, to mitigate the challenges for improved production and income. In this regard, this study confirms previous research and demonstrates that the use of technologies has been useful to banana smallholders.

On the other hand, this study also sought to explore the context of how technology might better match the needs of farmers. To this end, this study discovered two key issues on the current state of Malaysia's banana industry: first, the smallholders perceive the currently available bio-based technologies on improving banana production as somewhat inadequate, and two, the banana industry has not received appropriate attention from the government.

The farmers, who have been struggling with seasonal flooding, have been hoping for new technologies to mitigate flood impacts, such as flood-tolerant banana varieties. They have been hoping also for disease- and pest-resistant banana varieties due to frequent disease outbreaks. These outbreaks have had devastating impacts on their plantations and incomes, thus, their request for the Malaysian government and researchers to develop new banana varieties that are resistant to diseases such as *Fusarium* and Moko. As farmer 18 said, "There are no new technologies developed…but we can clearly see that our local banana industry is severely impacted by Moko disease. I believe it is important to find a solution to solve this problem."

It appears that the farmers were not aware of the new technologies or did not have access to them.

Some of the farmers also voiced their concerns over the vigor of TC banana plantlets since disease outbreaks have destroyed their plantations. They were under the misconception that TC plantlets are vigorous and can survive against any pathogens, but this may not necessarily be the case. An agriculturist we consulted on this matter explained that TC plantlets are delicate and require disease-free soils for optimum performance. We found out that some farmers who used TC plantlets did not take the first step of measuring the soil health; as such, TC plantlets were planted in infested soils. This had resulted in significant losses to the farmers as they had to destroy the diseased crops.

Prospects of Emerging Technologies to Overcome Challenges in Banana Cultivation

The key lesson from this study is that banana cultivars in Malaysia are highly vulnerable to disease outbreaks, particularly *Fusarium*, Moko, and Sigatoka. The prevalence of these diseases has been reported also in other regions (Ploetz 2015), prompting global efforts to bridge the knowledge gap in banana genomics and breeding (Global Musa Genomics Consortium 2002). Additionally, multi-partner collaborations have been established to develop improved banana varieties; a few new transgenic lines are currently being trialed in open fields (Pua et al. 2019). Joining the international research initiatives, Malaysian universities and research institutes have carried out promising research to improve disease tolerance for local banana varieties (Baharum et al. 2018; Jamil et al. 2022). As these initiatives are preliminary, more funding incentives should be allocated to sustain such endeavors, safeguarding the future of Malaysia's banana industry.

Further, improvement of existing diagnostic tools is also important to prevent and control the occurrence and severity of plant diseases, while minimizing pesticide costs, environmental impacts, and yield losses. In traditional agriculture, smallholders often rely on simple visual observations and their experience, as well as advice from agricultural extension officers, to detect diseases and assess their severity. However, the conventional approach is limited in its ability to identify and control diseases, making it difficult for farmers to make timely decisions on appropriate on-farm interventions (Thomas et al. 2018). Recent developments in AI-based computer vision automated approaches illustrate their potential to

improve the timeliness and accuracy of diagnostic tools for controlling crop diseases (Amara et al. 2017; Selvaraj et al. 2019). Precision agriculture can also be applied to develop smart irrigation techniques that can control the impact of flooding in agricultural farms (Keswani et al. 2019).

This study also affirms that effective communication among farmers, extension agents, and researchers remains a critical challenge to be addressed. With the advances in digital technology, smallholder banana farmers can make use of digital platforms that can facilitate data and knowledge exchange among stakeholders across all levels. The digital platforms would also enable farmers to share on-field observations, which could complement crowd-sourced environmental data, as well as historical and real-time data, enabling more meaningful data analyses for monitoring and prediction of disease events for future actionable farming interventions (McCampbell et al. 2018). The ICT approach can also be used as a new form of social interaction between farmers and research scientists so that research focus can better match the needs of farmers (Kindred 2015).

CONCLUSION

This qualitative study explores the challenges faced by smallholder banana farmers in Malaysia and elucidates the role of bio-based technologies in addressing the farmers' challenges. Results show that maintaining a banana plantation is particularly challenging due to rising production cost, flood threats, disease outbreaks, and pests. To address these challenges, farmers have used bio-based technologies like tissue culture of plantlets, which provides many significant benefits such as uniform and more rapid plant growth compared with plants grown from conventional suckers, and good quality harvest.

On the other hand, the currently available technologies are not yet able to protect vulnerable cultivars from plant diseases such as *Fusarium*, Moko, and Sigatoka. Hence, it is imperative that the science community finds solutions to the challenges, such as by developing new resistant varieties using modern biotechnological approaches and/or using AI- or ICT-based applications. Important also is the need for more active engagements and communication with smallholder banana farmers to reduce their misconceptions and to empower them with correct information and access to technology.

LIMITATIONS

While this study has generated useful insights on the current landscape of the smallholder banana industry in Malaysia, particularly the challenges faced and the extent of use of bio-based technologies by the farmers, the qualitative findings need to be further verified with rigorous quantitative analysis to yield robust statistical results that capture more completely the impacts of bio-based technologies on banana production.

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