academicJournals

Vol. 12(29), pp. 4603-4613, 17 July, 2013
DOI: 10.5897/AJB12.2868
ISSN 1684-5315 ©2013 Academic Journals
http://www.academicjournals.org/AJB

African Journal of Biotechnology

Full Length Research Paper

Farmers' awareness and perceived benefits of agro-ecological intensification practices in banana systems in Uganda

D. Ochola*, W. Jogo, W. Ocimati, A. Rietveld, W. Tinzaara, D.A. Karamura and E. B. Karamura

Bioversity International, P. O. Box 24384, Kampala, Uganda.

Accepted 17 July, 2013

Declining soil fertility and pests and diseases are major constraints to banana productivity in smallholder farming systems in Uganda. This study explored farmers' awareness and perceptions on agro-ecological intensification (AEI) practices for addressing these constraints in five banana-growing districts in Uganda. Stratified random sampling procedure was used to select 60 households for a survey from different agro-ecological zones and banana production systems. The household survey was complemented with focus group discussions to obtain qualitative data on farmer perceptions on benefits and constraints to AEI application on-farm. Thematic content analysis and descriptive statistics were used to analyze data. Results of the study show that most of the interviewed farmers were aware of the AEI practices although not all those aware had adopted the practices. Farmers were motivated to apply AEI practices perceived to offer multiple benefits: pest and disease management, enhanced productivity, soil fertility improvement and ecological adaptability. Major constraints to application of AEI practices by farmers include insufficient knowledge, labour intensiveness and limited access to markets. A transition towards intensification of smallholder banana systems requires that the full range of ecosystem services provided by AEI practices are recognized and valued by farmers. Therefore, empowering farmers with knowledge on their agro-ecological systems and locally adapting AEI practices is essential for realization of benefits and wider adoption of AEI practices.

Keywords: Agro-ecological intensification (AEI), awareness, banana, perceived benefits, smallholder, Uganda.

INTRODUCTION

Musa species (banana and plantain) are key crops in Uganda, supporting the livelihoods of millions of smallholder farmers who rely on it for food and income (Nowakunda et al., 2010). With an estimated total annual production of 10 million tones, Uganda is the second largest producer of bananas after India (FAOSTAT, 2003). The crop is grown predominantly by smallholder farmers on approximately 1.5 million hectares, equivalent to 38% of total arable land (Nowakunda and Tushemereirwe, 2004). Per capita consumption is estimated at 400 - 600 kg per year (Tushemereirwe et al., 2000; Karamura et al., 2008) which is among the highest in the world. Besides own consumption, the banana crop contributes to farmers' incomes through sales in raw form and other value-added products such as chips, cakes, wines, juice and flour (Karamura et al., 1991; Karamura, 1998). Moreover, different parts of the crop can be used for other domestic and industrial uses: leaves and

*Corresponding author. E-mail: d.ochola@cgiar.org. Tel: +256 414 286 213. Fax: +256414286949.

Abbreviations: AEI, Agro-ecological intensification; **IPM,** integrated pest management; **ICM,** integrated crop management; **NAADS,** National Agricultural Advisory Services.

pseudostems are principle sources of mulch for maintaining and improving soil fertility and moisture; leaf sheath fibers for thatching, handicrafts and clothing; leaves for wrapping foods; peels and pseudostems are valuable livestock fodder (Nelson et al., 2006; Pillay and Tripathi, 2007).

In spite of its importance, banana productivity has been declining since the 1970s in the traditional growing areas of central Uganda, at the same time there was an unprecedented geographic shift in banana cultivation towards non-traditional growing areas of southwestern Uganda (Gold et al., 2000; Bagamba et al., 2010). Low banana productivity has been attributed to worsening banana pests and diseases and declining soil fertility (Gold et al., 1991, van Asten et al., 2010). These two problems are inter-related, as low soil fertility reduces host plant vigor and leads to increased susceptibility to pests and diseases (Patriquin et al., 1995; Spann and Schumann, 2010). The major pests and disease problems on banana in Uganda include weevils, nematodes, *Fusarium* wilt, black sigatoka, banana streak virus and more recently Xanthomonas wilt (Gold et al., 1991; *Tushemereirwe* et al., 2004).. In addition to these, banana farmers are also faced with an array of abiotic constraints including low farm gate prices, limited access and high input costs, lack of output market linkages, financial credit, information and technologies, and climate change.

Due to rapid growth in population and lucrative market opportunities (that is, urban, regional and international), there is a real need for increased banana production for food security and to meet market demand. Although past increases in agricultural production depended largely on increasing land area utilized, this is no longer feasible in smallholder farming systems, as land has become a major limiting factor and fallow periods are reducing due to pressures of an increasing population. Furthermore, expanding agriculture by opening up new areas is a costly option due to competition for land resources with other equally important services such as biodiversity maintenance and other ecosystem services (Eppink et al., 2004). The food crisis in 2007 highlighted the vulnerability of global food supplies, and a need for agricultural systems that are highly productive, highly sustainable, and contribute to the progressive realization of the human right to food (De Shutter, 2011; Dobermann and Nelson, 2013). In order to save and grow - increasing agricultural productivity while preserving the environment, the agendas of food security and sustain-ability both require changes towards more sustainable production and consumption models (FAO, 2012). The desirable model of agriculture must possess proven results for fast progress in the concretization of the human right for many vulnerable groups, besides showing strong conceptual connections with the right for food (De Schutter, 2011; Méndez et al., 2013).

Two alternative models for intensifying smallholder agriculture are discussed in the following literature. The first is the Green Revolution model which emphasizes increasing productivity through use of improved varieties and intensive use of external inputs such as fertilizers and pesticides (Gabreselassie, 2006). Although there is ample evidence that the Green Revolution was a spectacular success credited with raised agricultural productivity gains, particularly in staple crops like wheat, maize and rice, main drawbacks with this model were the associated negative environmental costs that undermined the long-term sustainability of agro-ecosystem. For instance, the loss of yields due to pests in many crops, despite the substantial increase in the use of pesticides is a symptom of the environmental crisis affecting agriculture (Altieri and Rosset, 1995). Indeed one of the main global challenges for agricultural development is how to manage agricultural landscapes to achieve food security and poverty reduction without degrading the environment and biodiversity, which are central for maintaining the long term productivity of agro-ecosystems (Perfecto and Tscharntke, 2012). With regards to the growing discontent with the Green Revolution has led to the seeking of alternative models for intensification have been sought that draw more effectively on production ecology principles to improve the productivity and efficiency of agriculture while reducing negative environmental impacts (Dobermann and Nelson, 2013).

Within the context of sustainability, agro-ecological intensification (AEI) has emerged as an alternative paradigm for transforming agriculture. It is defined as producing more output from the same area of land while reducing the negative environmental impacts and at the same time increasing contributions to natural capital and the flow of ecosystem services (Collette et al., 2011; Pretty et al., 2011). The key principles of this approach are the explicit integration of biological and ecological processes (for example, nutrient cycling, nitrogen fixation, soil regeneration, competition) to increase agricultural production and use efficiency of external inputs, labor, and natural resources and to reduce losses to abiotic and biotic stresses (Côte et al., 2010; Doré et al., 2011).

It is important to note that AEI does not mean the exclusion of external inputs per se but implies designing sustainable production systems that save on external inputs and are less harmful to the environment and health. Notably, AEI builds on important capital assets for agricultural systems such as locally available resources, traditional farming practices and indigenous technical knowledge (Onwonga, 2009; Doré et al., 2011). The approach ultimately builds resilient livelihoods by sustainably increasing productivity of agricultural systems, enhancing environmental service provision, improving economic benefits and nutrition options of rural families, reducing risks from pests and diseases, increasing equity in rural communities and self determination of rural people, (Altieri, 1998; Pretty et al., 2006; Wezel et al., 2009; Fonte et al., 2012).

Despite soil fertility and pests and diseases being major constraints to banana production in Uganda, fertilizers and pesticides are not widely used by smallholder farmers, due to lack of access to the inputs and high prices (van Asten et al., 2010). This presents an opportunity for the promotion of AEI in managing soil fertility and pests and diseases in banana-based smallholder farming systems (Côte et al., 2010). Given its roots in integrated pest management (IPM), integrated crop management (ICM) and agro-ecology, AEI has great potential for the creation of environmental conditions less favorable to pests and diseases but more favorable for vigorous and healthy crop growth and active growth of beneficial organisms (Staver, 2002; Collette et al., 2011; Gomiero et al., 2011). The aforementioned ecologically-based pest management alternatives arose in response to the routine use of pesticides, which had resulted in greater application, pest resistance and emergence of secondary pests (Altieri and Rosette, 1995; Côte et al., 2010).

Driven by pressures to reduce use of pesticides, chemical fertilizers, fossil fuels and water, banana growers are beginning to implement numerous non-chemical agro-ecologically-based strategies (that is, manure application, mulching, leaf pruning, de-budding, destroying infected plants, host plant resistance, crop rotations, intercropping, pest-free tissue culture plants, pheromone trapping of insects and natural enemies) for controlling banana pests and diseases complexes (Côte et al., 2010; Doré et al., 2011). A recent study by Karamura et al. (2013) showed that AEI practices such as manure application and mulching can be effective in addressing banana pests such as nematodes and therefore reduce yield losses from these pests. However, the same study also showed that, due to the knowledge-intensive nature of AEI, effective deployment of these practices at the farm level is influenced by farmers' knowledge of their agro-ecosystems and the capacity for ecological reasoning. These two aspects also shape farmer's perceptions on the relevance and perceived benefits of AEI practices, which in turn influences actual application of the practices. This study intends to build on this work by further exploring the aspects of farmers' awareness of the practices and perceived benefits or constraints of AEI application using a combination of quantitative and qualitative approaches.

MATERIALS AND METHODS

An exploratory study was conducted between September and October 2011 to collect information on awareness and perception of agro-ecological intensification (AEI) practices among smallholder banana farmers in Uganda. Data were collected using three complimentary methods: household survey, focus group discussions and direct observations. To avoid bias that may arise from influences by other farmers who participated in group discussions, the household survey was conducted first. A stratified random sampling procedure was used to select 60 households from different agro-ecological zones and banana production systems (Table 1) for interviews with the structured questionnaire. Agro-ecological zones were delineated based on elevation: Low-altitude (< 1200 masl), mid-altitude (1201-1600 masl) and high-altitude (> 1600 masl). Production systems were defined based on the predominant *Musa* type: East African highland banana ('Matooke') or Pisang Awak ('Kayinja'). The districts of Kyankwanzi, Sembabule, Lwengo, Bushenyi and Mitooma were purposively selected to represent each agro-ecological zone and banana production system.

During the interviews, the male or female household-heads were the targeted respondents, although any adult with familiarity on banana production in the household was interviewed in the absence of household head. The questionnaire covered aspects on awareness of the different AEI practices, sources of information, and applied constraints and benefits of the practices. Additional information was gathered through direct observations by enumerators involved in the household surveys and documented in the form of field notes. After the household interviews, focus group discussions were held to collect complimentary qualitative information on benefits and constraints of AEI practices in the community. Participants for focus group discussions were farmers known to have better-than-average knowledge of banana farming that is, have been involved in banana production for longer periods of time. These farmers were selected based on information provided by key informants, who were mainly extension officers in the study areas. The selection criterion enabled the capture of longitudinal variability in application of AEI practices. Responses from farmer interview and focus group discussions were translated verbatim and imported into the computer programme ATLAS.ti7 (Cincorn Systems Inc., Berlin, Germany). Different themes and categories in the interview transcripts portraying farmers' perception of AEI were identified by thematic content analysis. Searches were conducted through the data to qualify themes and to remove phrases and words associated with duplications. Descriptive and comparative statistics (that is, means, percentages and cross-tabulations) were used to show the level of awareness and application of AEI practices among the banana farmers were generated using statistical package for SPSS version 17 software (IBM Corporation, New York, USA). Pearson's product moment correlation coefficient (chi-square test) was used to test for significance of associations between awareness and perception on the application of AEI practices in banana cropping systems in Uganda.

RESULTS

Demographics

The respondent characteristics and distribution is given in Table 2. On average, majority (51.7%) of banana farmers were women, 79.2% were concentrated in the mid-altitude zone while 64.3% had greater preference for Matooke cooking banana. Besides, 77.8% of males had a particular inclination towards Kayinja beer-banana. This reiterates the fact that feeding the household is a priority of women in rural agriculture whereas most men are keen to engage in agricultural ventures that generate cash income. Over 58% households comprised between five and nine members, implying that labour endowments for banana management were sufficient irrespective of banana production system and agro-ecological zone. Notably, large families experience less uncertainty with regard to production risks and far better positioned to

Table 1. Sampling framework.

Agro-ecological zone	Production system	District	Sampled household
< 1200 masl	EAHB	Kyankwanzi	12
	Kayinja		12
1200 - 1600 masl	EAHB	Lwengo	18
	Kayinja	Ssembabule	6
> 1600 masl	EAHB	Bushenyi Mitooma	12

Table 2. Characteristics of respondents.

Variable	Gender		Production system		Agro-ecological zone			All (n = 60)
	Male (n = 29)	Female (n = 31)	Kayinja (n = 18)	EAHB (n = 42)	Low (n = 24)	Mid (n = 24)	High (n = 12)	
Age (years)	43.1	45.4	44.3	44.3	41.3	48.7	41.6	44.3
Education level (years)	8.2	6.3	6.7	7.5	7.5	6.3	8.6	7.3
Household size	5.3	5.7	4.6	5.9	5.4	5.7	5.5	5.5
Farm size (hectares)	3.6	2.5	3.7	2.8	3.1	2.6	3.9	3.1
Banana farm (hectares)	1.0	1.1	1.0	1.1	1.1	1.2	0.9	1.1
TLU*	1.7	2.1	0.8	2.4	1.5	1.2	4.1	1.9

benefit from adoption of good management practices. Age of farmers was variable across gender and agro-ecological zone. Women were slightly older (45 years) while the mid-altitude zone had the oldest (49 years) (Table 2). In general, interviewed farmers were over 40 years of age, indicating a progressively ageing farming community in rural Uganda. Considering that age significantly explains efficiency in agricultural ventures, about 90% farmers were quite experienced (>10 years) in banana cultivation despite having a low education level of about 7 years (primary education).

Generally, women farmers had the least level of education of about 6 years compared to 8 years for men, reflecting a history of bias against girls in education. Although farmers had considerably large farm sizes (3.1 ha) the operational capacity for banana production was restricted to 1.1 ha irrespective of production system or agro-ecological zones. Gender inequalities in land entitlement and distribution were visible among smallholder banana farmers.

For example, men had a larger landholding (3.6 ha) compared to women (2.5 ha). We noted that existing kinship ties and power relationships within traditional governance structures continue to frustrate women from ownership of land. However, women were observed to have a lot more land to the production of bananas compared to men (Table 2). A relatively low livestock numbers (1.9 TLU) and yet variable distribution was visible across gender, production system and agro-ecological zone. Ownership of livestock was particularly high among women, cooking banana systems and high-altitude zone. Livestock was a minor enterprise and apparently seemed to receive little attention particularly in beer banana systems (Table 2).

Awareness of agro-ecological intensification in banana systems

A total of 10 AEI practices were commonly practiced across the study sites (Table 3). Awareness was generally high (93.4 to 100%) among smallholder banana farmers, irrespective of the banana production system and agro-ecological zone (Table 3). The incentive for elevated levels of awareness among banana farmers may, in part, be attributed to various on-farm research initiatives and extension services aimed at bringing agricultural knowledge closer to the grassroots. Farmers were most conversant with traditional AEI practices such as crop residue mulching, intercropping with coffee or legumes, soil-water conservation, detrashing (removal of dead leaves) and harvested pseudostem splitting. Moreover, not all farmers who were aware of AEI practices were actually applying them on-farm. For example, despite 98% awareness recorded for the use of clean planting materials, only 67% use clean planting materials.

Similarly, despite 100% awareness on the value of soil and water conservation, only 45% applied the practice on farm (Table 3). Thus awareness did not necessarily translate into application of AEI practices. Pruning of dead banana leaves (93.3% of respondents) and removal

Table 3. Percentage of farmer awareness and application of AEI practices in smallholder banana production systems in Uganda*.

AEI practice	Not aware	Aware but not applying	Aware and applying	Total awareness
Manure application	3.3	51.7	45	96.7
Mulching	0	28.3	71.7	100
Intercropping	0	38.3	61.7	100
Soil-water conservation	0	55	45	100
Improved banana varieties	1.7	33.3	65	98.3
Clean planting materials	1.7	31.7	66.7	98.4
Rouging of infected plants	6.7	26.7	66.7	93.4
Removal of male buds	1.7	10	88.3	98.3
Pruning of dead leaves	0	6.7	93.3	100
Pseudostem splitting	0	31.7	68.3	100

practices. The removal of dead leaves from the bananaplant has been promoted as one of the integrated management options for black sigatoka (Vargas et al., 2009; Engwali et al., 2013). It is also a common practice were farmers intercrop bananas with legumes (Ocimati et al., CABI book, in press). Timely removal of male bud has and is still being promoted for the control of insect-mediated spread of banana *Xanthomonas* wilt (Eden-Green, 2004; Tinzaara et al., 2006) and is widely applied due to the high prevalence of BXW in the study sites. This practice also improves bunch yield. AEI practices such as use of clean planting materials, rouging of infected planting materials and pseudostem splitting with moderately high application rates (65 - 68%) have also been promoted for the control of *Xanthomonas* wilt that has devastated banana production in the region (Biruma et al., 2007; Tripathi et al., 2009). In contrast, manure utilization (45%) and soil water conservation (45%) were least applied on-farm (Table 3).

The application of AEI practices varied between gender, production systems and agro-ecological zones (Table 4). Except for intercropping, use of clean planting materials and improved banana varieties, more women than men practiced AEI practices on farm. Despite being less educated than males, women by virtue of their active involvement in household food production gain knowledge and experience which enhance their adoption of knowledge-intensive AEI practices. However, there was no significant difference ($p \leq 0.05$) in application of most AEI practices by gender, except for mulching and pruning of dead leaves, practiced more by women and the use of clean planting materials practiced more by the men (Table 4). Significantly different levels of AEI application were visible between Matooke-cooking and Kayinja beer-type banana systems, except for intercropping and use of clean planting materials. Higher levels of deployment of AEI practices were observed in the highland-cooking than in beer-type banana systems. In general, Matooke were more intensively managed than of male buds (88.3%) were the most applied AEI the Kayinja systems. Conversely, Kayinja systems are generally considered as tolerant to low soil infertility and low levels of management (Gaidashova et al., 2008). For example no farmers applied manure in the Kayinja systems in this study. Significantly higher levels of AEI application ranging between 75 and 100% were also noted in the high-altitude agro-ecological zone (Table 4). It should be noted that this agro-ecological zone is dominated by the Matooke system that is intensively managed. Apparently, some of the highland banana cultivars were actually for beer in this system.

Perceived benefits of agro-ecological intensification in banana systems

Examination of verbatim transcripts revealed the diverse perceptions farmers have on the benefits of AEI practices. Farmers' perceptions on AEI varied with gender and production system, and to a lesser extent by agro-ecological zones. Majority of farmers cultivating Matooke bananas, who are mainly woman-headed households, actually perceived multiple benefits from AEI application. Examples of the multiple benefits of some AEI practices are illustrated in the following quotes:

"When I put manure in my banana garden, I harvest bigger banana bunches….manure helps my plants to grow well….it also helps to soften the soil"

"Mulching....prevent weeds from growing…keeps water in the soil…soil is more fertile…prevents rainwater from taking away soil"

"Removal of male bud is important for controlling the spread of wilt disease in my field…if I don't remove it the size of my bunch is much smaller...I later use it for feeding my animals"

Table 4. Differences in percentage application of agro-ecological intensification practices by gender, production system and agro-ecological zone.

AEI practice	Gender			Production system			Agroecological zone			
	Male (n = 29)	Female (n = 31)	X^2-test	Kayinja (n = 18)	EAHB (n = 42)	X^2-test	Low (n = 24)	Mid (n = 24)	High (n = 12)	X^2-test
Manure application	34.5	54.8	3.25 ^{ns}	0.0	64.3	22.50 **	29.2	45.8	75.0	12.15 **
Mulching	51.7	90.3	10.99 **	44.4	83.3	9.38 **	45.8	87.5	91.7	13.22 **
Intercropping	69.0	54.8	1.26 ^{ns}	55.6	64.3	0.41 ^{ns}	79.2	37.5	75.0	9.94 *
Soil-water conservation	37.9	51.6	1.13 ^{ns}	11.1	59.5	11.93 **	8.3	54.2	100.0	28.52 **
Improved banana varieties	69.0	61.3	1.76 ^{ns}	44.4	73.8	6.15 *	58.3	62.5	83.3	3.56 ^{ns}
Clean planting materials	79.3	54.8	6.10 *	66.7	66.7	2.45 ^{ns}	58.3	58.3	100.0	8.82 *
Rouging of infected plants	55.2	77.4	5.07 ^{ns}	33.3	81.0	14.05 **	50.0	66.7	100.0	11.82 **
Removal of male buds	79.3	96.8	4.66 ^{ns}	61.1	100.0	18.49 **	87.5	83.3	100.0	2.26 ^{ns}
Pruning of dead leaves	86.2	100.0	4.58 *	77.8	100.0	10.00 **	83.3	100.0	100.0	6.43 ^{ns}
Pseudostem splitting	65.5	71.0	0.21 ^{ns}	27.8	85.7	19.54 **	54.2	66.7	100.0	7.82 *

*Significant at $p \leq 0.05$; **significant at $p \leq 0.01$; ns, not significant.

"I intercrop banana with other crops in order to harvest a variety of crops from small acreage...I get enough money from coffee in bananas"

In general, when benefits were thematically ranked according importance, the role of AEI in the management of banana pest and disease complexes was ranked highest (Figure 1). The following practices were perceived to be options for integrated management options against pest and diseases: removal of male buds (61.1%), use of tissue culture materials (65.7%), pruning of dead leaves (70.6%) and destroying infected plants (81.4%) (Figure 1).

Notably, rouging of diseased plants is an effective method of eliminating existing sources of inoculum and reducing opportunities of further spread of banana Xanthomonas wilt (Eden-Green, 2004). The importance of AEI in disease management is illustrated verbatim in the words of a farmer:

"I used to cut the male buds using cutting tools or would just leave them on the plants. Luckily at that time plants had no problems of diseases. Later, I learnt that Xanthomonas wilt disease was transmitted through male buds and cutting tools. Therefore, I immediately began controlling the disease in my plantation by disinfecting all farm tools with fire and also removing male buds with a forked stick."

In addition, importance of AEI for enhanced crop yields and ensuring improved soil fertility were ranked second and third respectively since food security and soil fertility replenishment are key agricultural priorities in most rural communities (Figure 1). Farmers perceived equally (51%) the deployment of improved banana varieties and manure application for increasing yields and improving soil fertility, respectively (Figure 1). Manure is considered a key input for smallholder farming systems, especially where cost and availability limit the use of inorganic fertilizers (Harris and Yusuf, 2001; Mustafa-Musukwa et al., 2011).

It is obvious that continuous cropping with very little investment in soil fertility replenishment was the cause of the noted declines in banana productivity witnessed over the years. The use of organic amend-ments in agriculture contributes immensely to converting much of the poor fragile land into stable productive zones. Despite being core at the heart of AEI, farmers gave less explicit attention to the benefits associated with the use of locally available resources and indigenous knowledge (Figure 1).

This observation seems to concur with some of the output from the focused group discussions, showing that farmer perceived benefits of AEI do not necessarily align well with what researchers consider priority benefits to smallholder livelihoods. Nevertheless, entrenching knowledge on the importance of AEI practices towards improved soil fertility, enhanced crop yield, pest and disease control is critical for enhancing their adoption by the smallholder farmers.

Constraints to agro-ecological intensification in banana systems

The household survey showed that several factors constrain smallholder banana farmers from implementing AEI practices that they actually perceived as beneficial on their farms (Figure 2). The four main constraints to AEI application ranked according to importance were 1) labour intensive, 2) does not work, 3) insufficient knowledge on practice and 4) limited / lack of access to

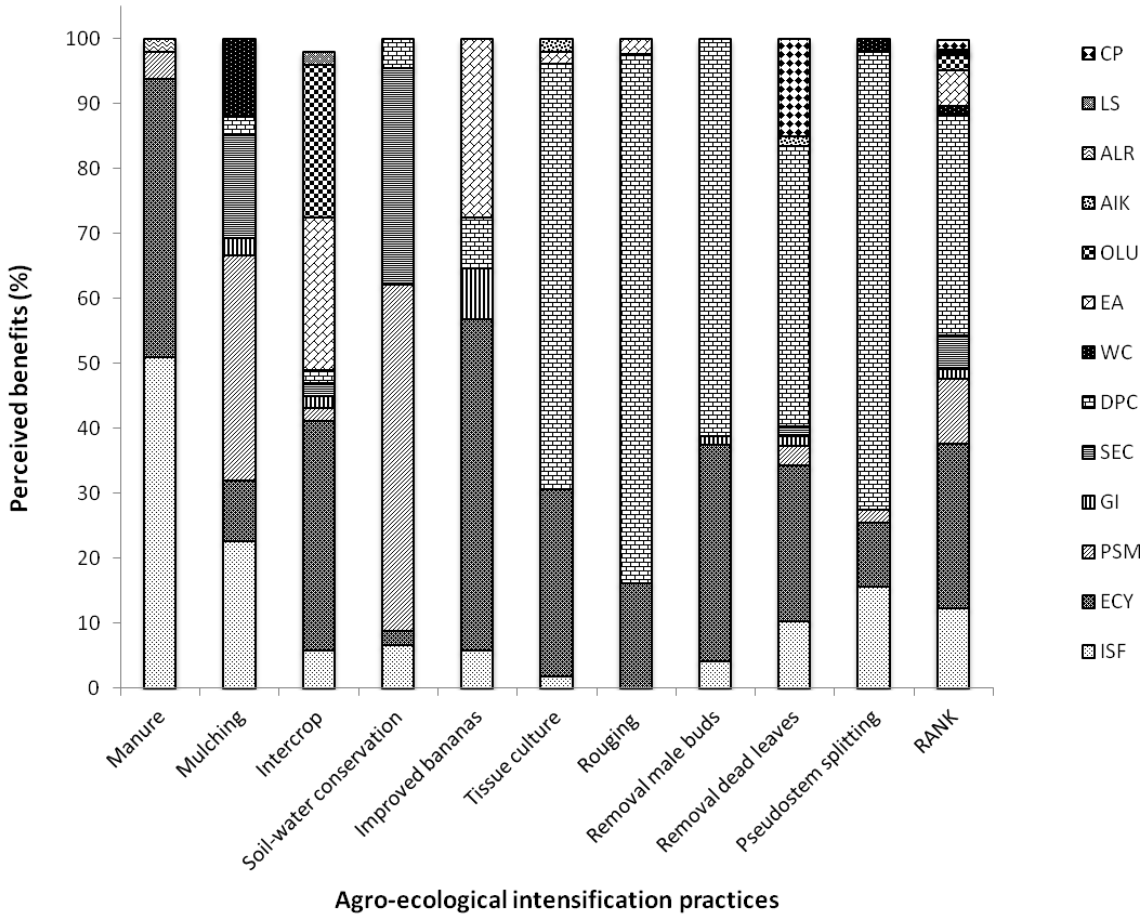

Figure 1. Perceived benefits of agro-ecological intensification practices in smallholder banana production. Perceived benefits: ISF, Improved soil fertility; ECY, enhanced crop yield; PSM, preserve soil moisture; GI, generate income; SEC, soil erosion control; DPC, disease and pest control; WC, weed control; EA, ecological adaptability; OLU, optimized landuse; AIK, availability of knowledge; ALR, availability of local resources; LS, labour saving; CP, clean plantation.

inputs (Figure 2). The most labour intensive AEI practices were identified as harvested pseudostem splitting, removal of male buds and pruning of dead leaves. Farmers also highlighted insufficient knowledge on how to appropriately handle and manage tissue culture materials and improved banana varieties in order to optimize their benefits. They also revealed that limited accessibility to pest and disease-free tissue culture materials and improved banana varieties greatly limits their capacity to deploy these practices on-farm, so that their only recourse is to use maiden suckers. Besides, limited availability and high cost of organic manures was identified as a constraint to their use for soil fertility amendment, which could partly be attributed to the documented decline in livestock populations. On the other hand, mulching was mainly constrained by its high demand for labour and limited availability due to competition from other uses. For example, grasslands between home gardens were not only used for grazing livestock, but were also a source of grasses for mulching in banana-based farming systems (Mwijage et al., 2009). Results showed that the soil-water conservation practices were mainly constrained by high labour demand while insufficient knowledge was a key constraint to application of the recommended practice of rouging diseased plants in the control of banana Xanthomonas wilt. Surprisingly, several misconceptions seem to cloud smallholder farmers' perceived importance of AEI practices in production of banana. In particular, thoughts about negative effects of livestock manure on growth of bananas were most prevalent among farmers who had recently ventured into banana production. For instance, seldom application of manure, rouging of infected plants and debudding were for fear of possible negative effects on soil health, food security and beer potency as illustrated below:

"Using cow dung as manure in banana plantations will destroy my plants…..I am afraid that after destroying diseased plants, I will lack banana leaves to wrap food

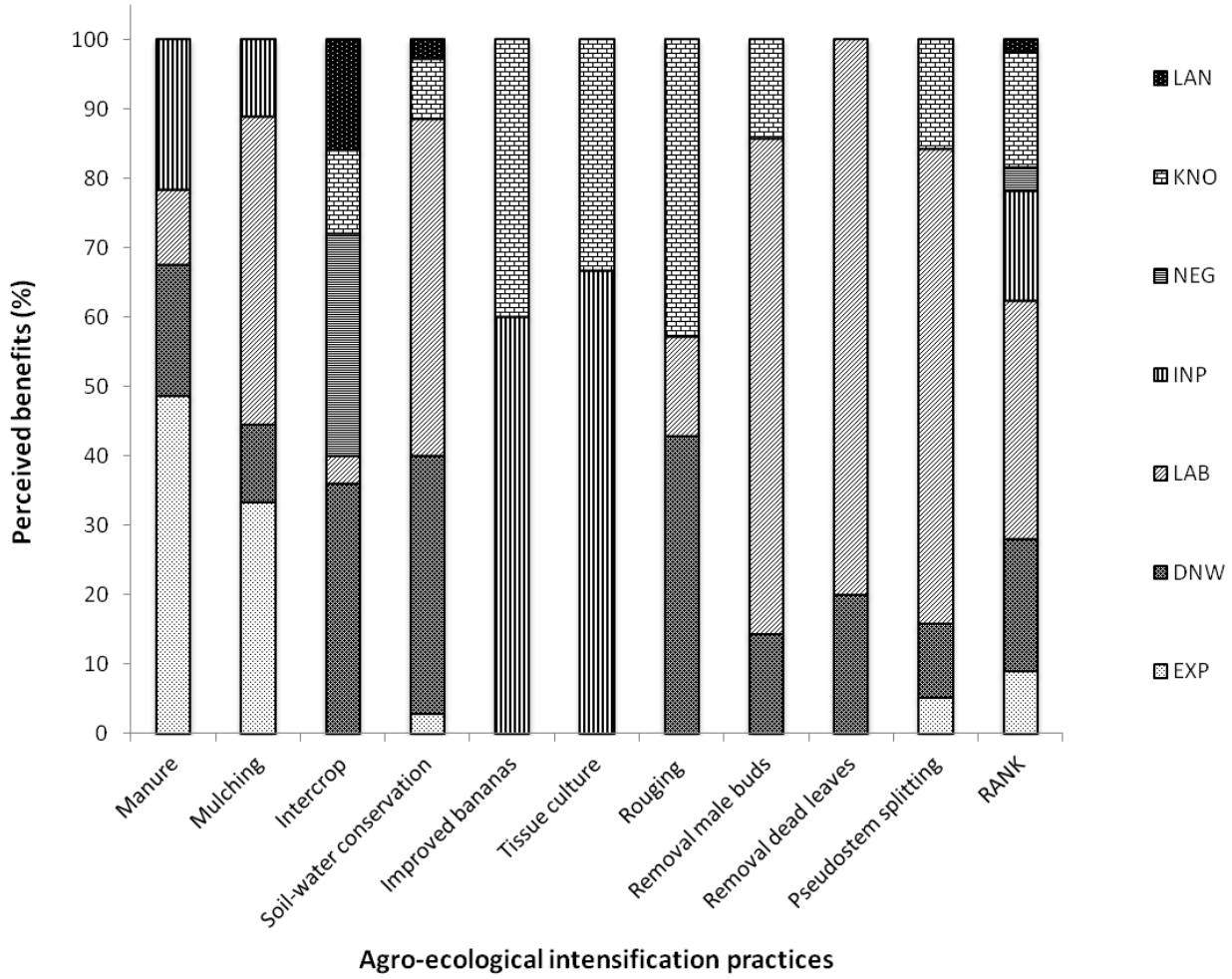

Figure 2. Perceived constraints of agro-ecological intensification practices in smallholder banana production. Perceived constraints: EXP, High cost of application; DNW, does not work; LAB, labour intensive; INP, lack of access to inputs; NEG, negative effects on bananas; KNO, insufficient knowledge on practice; LAN, limited farm land.

while cooking…..I believe that if the male buds are removed from Kayinja beer bananas, the exuding sap will reduce the eventual strength of the juice or beer I make."

These misconceptions are a reflection of the inadequate knowledge that results in wrong application of practices and competing cultural beliefs. For example, since fresh livestock manure contains high levels of salt and ammonia toxicity, it is capable of scorching leaves when directly applied to growing plants (University of Minnesota / Extension, 2000).

DISCUSSION

The exploratory study above provides insights into some of the important features of smallholder banana systems in Uganda. The preponderance of evidence from Uganda indicates that banana productivity has stagnated or declined across majority of traditional areas over the past 40 years and that in many instances a shift in production can be cited towards more non-traditional areas (Gold et al., 2000; Bagamba et al., 2010). Large proportion of banana has been cultivated on a nearly continuous basis for many decades, few inputs have been applied and conservation measures have been inadequate in most places. Within the context of sustainable agriculture, these banana systems have not been sustainably managed to ensure better harnessing of ecosystem services such as food and drinking water, preserving and regenerating soils, fixing nitrogen and carbon, recycling of nutrients, filtering pollution among others. This study alludes to awareness, perceived benefits and constraints to AEI application in banana systems. Our findings reveal that large number of farmers were aware of the different AEI practices, in context that they are sensitized to its existence and fully understand its performance and requirements (Dubois et al., 2013). A major incentive for

elevated awareness, even among female banana farmers may, in part, have come from the mounting pressure from pests and disease and soil infertility. For example, AEI practices such as de-budding of male buds, uprooting of disease plants and use of clean plants that are currently promoted for managing banana Xanthomonas wilt were highly practiced across the study sites.

AEI builds on farmers' indigenous knowledge to understand the ecology of traditional farming systems, which once incorporated with elements of modern agricultural science, can lead to optimization of production (Altieri, 1995). Secondly, various on-farm research initiatives and extension services are aimed at bringing agricultural information closer to the grassroots; for instance, under the National Agricultural Advisory Services (NAADS) enterprise selection and development activities, farmer groups actively participate in the local decision-making process of identifying their own production priorities and what sort of resources to be allocated for enterprise development in their local area (Kyomugisha, 2008a). Farmer group membership has facilitated knowledge gathering and sharing, which points to the important role of social networks for knowledge dissemination (Dubois et al., 2013). Moreover, a major limitation to AEI in banana systems is that the great awareness did not necessarily translate into greater farm-level adoption. Several constraints persist to impede AEI application, even of practices perceived to be beneficial for banana productivity. Insufficient knowledge on the benefits and application of some of the AEI practices such as use of clean planting materials and rouging was noted in this study. Karamura et al. (2013) highlighted that AEI is context dependent and knowledge-intensive, since its application at the farm-level is influenced by agro-ecological and socio-economic considerations. Often farmers utilize technologies based on their relative advantages, compatibility, complexity, trial ability and observations (Sinja et al., 2004). This study shows that smallholder banana farmers perceived multiple benefits of AEI (including pest and disease management, enhanced productivity, soil fertility regeneration and ecological adaptability). This illustrates an increasing awareness by farmers that sustainable practices should be able to fulfill the twin objectives of meeting current societal needs and desires without jeopardizing the options for future generations (FAO, 2012).

This largely untapped potential of AEI in banana systems particularly emphasizes the profound differences in view point that have for long existed between scientific and traditional forms of knowledge (Cuéllar-Padilla and Calle-Collado, 2011). Previous research has shown that most scientists have condescending and misleading metaphors that local ecological knowledge is a cultural commodity while western science is absolute truth (Woodley, 2004; Oladele and Fawole, 2007). Actually farmers' indigenous knowledge is authentic despite certain irregularities that make it distinctive from scientific knowledge, which is most times based on semantic premises of necessary and sufficient conditions (Bentley and Baker, 2005). Local ecological knowledge is a dynamic interplay of a complexity of variables that is local beliefs, practice and context operatives in communities. Therefore, it is highly necessary for scientists to understand what farmers already know, do not know or misunderstand because their experiential knowledge is crucial for identification of innovative solutions and development of legitimate sustainable agricultural systems (Morse and Buhler, 1997; Bacon et al., 2008; Kindon et al., 2007). Other factors responsible for limited application or abandonment of AEI practices in banana included labour intensiveness and limited access to external inputs and markets. Although it is very important for banana farmers to be knowledge aware of AEI practices and their benefits, effect of education level on adoption of various technologies in agriculture has been emphasized in several studies (Fernandez-Cornejo et al., 2001; Roberts et al., 2004; Lambert et al., 2007).

Education level determines the household-head's competence to make strategic decisions related with farm productivity, incomes and nutritional wellbeing of that household (World Bank, 2007a; FAO, 2011). Apparently, limited educational experience of banana farmers in this study suggests lower analytic capabilities to interpret agricultural information and efficient allocation of available local resources to improve crop productivity (Rahman, 2003; Ogunlade et al., 2009; Sofoluwe et al., 2011). In this study, it was also observed that majority of smallholder farm operations are almost exclusively done manually and household labour is the key input. Depending on time demand of a particular task, crop management practices that require more time to accomplish risk being suspended or discarded because they directly compete for labour resources with other activities including leisure. So when labour intensiveness of AEI is cited as a critical factor impeding application, it could be that farmers perceive it to infringe on their legitimate right to off-farm activities and leisure.

By virtue of remoteness, a number of banana farming communities were disconnected from urban input and output markets, due to poorly developed and maintained road and communication systems (Bahiigwa, 2006). As a result, rural communities are poorly informed, both on technical options for responding to production and yield constraints and on market windows for greater prices (Côte et al., 2010). Worse still, existing markets are fragmented, which tremendously weakens the incentives for smallholders to invest in more productive agricultural technologies and instead opt for low external input subsistence commodities (Kyomugisha, 2008b; Salami et al., 2010).

Conclusion

Raising awareness is a critical point in trying to generate

knowledge that may impact farmers in different ways. Majority of AEI practices are knowledge intensive, therefore understanding farmer awareness and perceptions is essential for development of good practices required for averting the steady collapse of banana production systems in Uganda. On the other hand, limited on-farm deployment of AEI practices among smallholder banana farmers suggests increased importance for researchers and extensionists to create a framework of ensuring that farmers utilize relevant knowledge. Empowering rural farmers to become accustomed with AEI strategies is essential to achieve appropriateness of new options in local contexts and hence potential adoption. A transition towards intensification of smallholder banana systems requires that the full range of ecosystem services provided by AEI are recognized and valued if farmers are to enhance sustainability and productivity.

ACKNOWLEDGEMENTS

We thank the farmers who participated in this study and McKnight Foundation for the financial support.

REFERENCES

Altieri MA (1995). Agroecology: The science of sustainable agriculture. 2nd edition. Intermediate Technology Publications, London, UK. P. 433.

Altieri MA, Rosset P (1995). Agroecology and the conversion of large-scale conventional systems to sustainable management. Inter. J. Environ. Stud. 5:1-21.

Bacon CM, Méndez VE, Gliessman SR, Goodman D, Fox JA (eds.) (2008). Confronting the coffee crisis: Fair trade, sustainable livelihoods and ecosystems in Mexico and Central America. Cambridge, MA: MIT Press. ISBN: 978-0-262-52480-3. XII, p. 390.

Bagamba F (2010). Market access and agricultural production: the case of banana production in Uganda. VDM Verlag. pp. 176.

Bahiigwa G (2006). Access of Eastern African farmers to domestic and international markets: Opportunities and constraints. Invited paper prepared for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia, August 12-18, 2006.

Bentley JW, Baker PS (2005). Understanding and getting the most from farmers' Local Knowledge. In: Gonsalves, J., T. Becker, A. Braun, D. Campilan, H. De Chavez, E. Fajber, M. Kapiriri, J. Rivaca-Caminade and R. Vernooy (eds). Participatory Research and Development for Sustainable Agriculture and Natural Resource Management: A Sourcebook. CIP - ARD - IDRC. 1:58-64

Biruma M, Pillay M, Tripathi L, Blomme G, Abele S, Mwangi M, Bandyopadhyay R, Muchunguzi P, Kassim S, Nyine M, Turyagyenda L, Eden-Green S (2007). Banana Xanthomonas wilt: a review of the disease, management strategies and future research directions. Afr. J. Biotech. 6 (8):953-962.

Collette L, Hodgkin T, Kassam A, Kenmore P, Lipper L, Nolte C, Stamoulis K, Steduto P (2011). Save and grow: a policymakers' guide to the sustainable intensification of smallholder crop production**.** Food and Agriculture Organization of the United Nations (FAO), Rome (Italy). 2011. Rome (IT): FAO. X, 102 p. ISBN: 978-92-5-106871-7.

Côte F, Tomekpe K, Staver C, Depigny S, Lescot T, Markham R (2010). Agro-ecological intensification in banana and plantain (Musa spp): An approach to develop more sustainable cropping systems for both smallholder farmers and large scale commercial producers In: Dubois T, Hauser S, Staver C, Coyne D (eds) (2010). Proc. Int. ISHS-ProMusa Symp. on Banana and plantains: Harnessing International partnerships to increase research impact. Acta Hort. 2(879):457-463.

Cuéllar-Padilla M, Calle-Collado Á (2011). Can we find solutions with people? Participatory action research with small organic producers in Andalusia. J. Rural Stud. 27:372-383.

De Schutter O (2011). Agroecology and the right to food. Report presented at the 16th Session of the United Nations Human Rights Council [A/HRC/16/49]. March 8. United Nations Special Rapporteur on the Right to Food.

Dobermann A, Nelson R (2013). Opportunities and solutions for sustainable food production. Background paper for the High-Level Panel of Eminent Persons on the Post-2015 Development Agenda. Prepared by the co-chairs of Sustainable Development Solutions Network Thematic Group on Sustainable Agriculture and Food Production.

Doré T, Makowski D, Malézieux E, Munier-Jolain N, Tchamitchian M, Tittonell P (2011). Facing up to the paradigm of ecological intensification in agronomy: Revisiting methods, concepts and knowledge. Review article. Eur. J. Agron. 34:197-210.

Dubois T, Dusabe Y, Lule M, van Asten P, Coyne D, Hobayo J-C, Nkurunziza S, Ouma E, Kabunga N, Qaim M, Kahangi E, Mwirigi P, Mwaura P, Kisii D, Kizito H, Mugisha J (2013). Tissue culture banana (Musa spp.) for smallholder farmers: Lessons learnt from East Africa. Acta Hort. (ISHS) 986:51-59

Eden-Green SJ (2004). How can the advance of banana Xanthomonas wilt be halted? InfoMusa 13:38-41.

Engwali FD, Nfor TD, Alain K (2013). On-farm evaluation of deleafing frequency on the severity of black sigatoka disease *Mycosphaerella fijiensis* Morelet) and Yield of Banana (*Musa* spp.). (Am. J. Exp. Agric. 3(3):595-605.

FAO (2011). State of food and agriculture - Women in agriculture: Closing the gender gap for development. Food and Agricultural Organization of the United Nations, Rome, Italy.

FAO (2012). Towards the future we want: End hunger and make transition to sustainable agricultural and food systems. Food and Agricultural Organization of the United Nations, Rome, Italy.

FAOSTAT (2003). Food and Agricultural Organization (FAO), Statistics Division.

Eppink FV, van den Berg JCM, Rietveld P (2004). Modeling biodiversity and land use: urban growth, agriculture and nature in wetland area. Ecol. Econ. 51(3-4):201-216.

Fernandez-Cornejo J, Daberkow S, McBride DW (2001). Decomposing the size effect on the adoption of innovations: agro-biotechnology and precision agriculture. AgBioForum 4(2):124-136.

Gabreselassie S (2006). Intensification of smallholder agriculture in Ethiopia. Future Agricultures Consortium. Policy Brief 004.

Gaidashova VS, Karamera F, Karamura E (2008). Performance of introduced banana varieties in lowlands of Rwanda. Afr. Crop Sci. J. 16(1):9-16.

Gold CS, Bagamba F, Wejuli M, Karamura D, Kalyebara R (2000). Geographic shifts in highland banana production in Uganda. Acta Hortic. 540:55-62.

Gold CS, Ogenga-Latigo MW, Tushemereirwe WK, Kashaija I, Nankinga C (1991). Farmers perceptions of banana pest constraints in Uganda: Results from a Rapid Rural Appraisal In: Gold, C.S & Gemmill, B (eds). Biological and Integrated control of highland banana and plantain pests and diseases. Proceedings of a research coordination meeting, 12-14 November, 1991, Cotonou, Benin.

Gomiero T, Pimentel D, Paoletti M (2011). Is there a need for a more sustainable agriculture? Crit. Rev. Plant Sci. 30:6-23.

IRRI(2011). IRRI-Farm-level strategies for agro-ecological intensification. http://beta.irri.org/climate-change/Agro-Ecological_Intensification.html

Karamura DA (1998). Numerical taxonomic studies of the East African Highland Bananas (Musa AAA-East Africa) in Uganda. A thesis submitted for the degree of Doctor of Philosophy, Department of Agricultural Botany, University of Reading. p. 189.

Karamura EB (1991).The strategic importance of bananas/plantains in Uganda. Proceedings of a research coordination meeting for biological and integrated control of highland banana pest and diseases in Africa, 12-14 November, Cotonou, Benin.

Karamura EB, Jogo W, Rietveld A, Ochola D, Staver C, Tinzaara W,

Karamura DA, Kubiriba J, Weise S (2013). Effectiveness of agro-ecological intensification practices in managing pests in smallholder banana Systems in east and central Africa. Acta Hort. (ISHS) 986:119-126.
Karamura EB, Turyagyenda FL, Tinzaara W, Blomme G, Ssekiwoko F, Eden-Green SJ, Molina A, Markham R (2008). Xanthomonas wilt of bananas in East and Central Africa: Diagnostic and Management Guide. Bioversity International, Uganda.
Kindon S, Pain R, Kesby M (eds.) (2007). Participatory Action research approaches and methods. Connecting people, participation and place. Abingdon: Routledge. p. 260.
Kyomugisha E (2008a). Assessment of the enterprise selection and development process of the Ugandan National Agricultural Advisory Service. International Food Policy Research Institute. Uganda Strategic Support Program. Brief No. 3.
Kyomugisha E (2008b). Land tenure and agricultural productivity in Uganda. International Food Policy Research Institute. Uganda Strategic Support Program. Brief No. 5.
Lambert DM, Sullivan P, Claasen R, Foreman L (2007). Profiles of US farm households adopting conservation-compatible practices. Land Use Policy 24, no. 1(2007):72-88.
Méndez EV, Bacon CM, Cohen R (2013). Agroecology as a transdisciplinary, participatory and action-oriented approach. Agroecol. Sustain. Food Syst. 37(1):3-18.
Morse S, Buhler W (1997). Integrated pest management: ideals and realities in developing countries. Lynne Riener Publishers. pp.171.
Mwijage AN, de Ridder N, Baijukya F, Pacini C, Giller EK (2009). Exploring the variability among smallholder farms in the banana-based farming systems in Bukoba district, Northwest Tanzania. Afr. J. Agric. Res. 4 (12): 1410-1426.
Nelson SC, Ploetz RC, Kepler AK (2006). Musa species (bananas and plantains). In: Elevitch, C.R. (Ed.). Species Profiles for Pacific Island Agroforestry. Permanent Agricultural Resources, Holualoa Hawai'i. p. 33.
Nowakunda K and Tushemereirwe WK (2004). Farmer acceptance of introduced banana genotypes in Uganda. Afr. Crop Sci. J. 12(1):1-6.
Nowakunda K, Ngambeki D, Tushemereirwe WK (2010). Increasing small-scale farmers' competitive in banana (Musa spp.) production and marketing. Acta Hortic. (ISHS) 879:759-766.
Ogunlade MO, Agbeniyi SO, Oluyole KA (2010). An assessment of the perception of farmers on cocoa pod husk fertilizers in Cross River State, Nigeria. ARPN J. Agric. Biol. Sci. 5(4):1-4.
Oladele OI, Fawole OP (2007). Farmers' perception of the relevance of agriculture technologies in South-western Nigeria. J. Hum. Ecol. 21(3):191-194.
Onwonga R (2009). Towards increased agricultural productivity and food security in east Africa through capacity building in agro-ecological intensification. Background information to the CCRP-funded project 09-595.
Patriquin DG, Baines D, Abboud A (1995). Diseases, pests and soil fertility. In: Cook HF, Lee HC (Eds) Soil Management in Sustainable Agriculture. Wye College Press, Wye, England. pp. 161-174.
Perfecto I, Tscharntke T (2012). Agroecology, biodiversity and food security: transcending the land sparing debate. In: Book of Abstracts, Planet under Pressure. D3010601.
Pillay M, Tripathi L (2007). Banana. Chapter 15. In: Kole, C. (Ed.). Genome Mapping and Molecular Breeding in Plants. In: Fruits and Nuts. Springer-Verlag. 4:281-301
Pretty JN, Noble D., Bossio J, Dixon RE, Hine FW, de Vries PT, Morison JIL (2006). Resource-conserving agriculture increases yields in developing countries. Environ. Sci. Tech. 40:4.
Pretty JN, Toulmin C, Williams S (2011). Sustainable intensification in African agriculture. Int. J. Agric. Sust. 9(1):5-24.
Pretty, J. (2008). Agricultural sustainability: concepts, principles and evidence. Phil. Trans. Royal Soc. London. Series B. Biol. Sci. 363(1491):447-465
Rahman S (2003). Environmental impact of modern agricultural technology diffusion in Bangladesh: An analysis of farmers' perceptions and their determinants. J. Environ. Manage. 68:183-191.
Roberts RK, English BC, Larson JA, Cochran RL, Goodman WR, Larkin SL,-Mara MC,-Martin SW, Shurley WD, Reeve JM (2004).-Adoption of Site-Specific Information and Variable-Rate Technologies in Cotton Precision Farming. J. Agric. Appl. Econ. 36(1): 143-158.
Salami A, Kamara AB, Brixiova Z (2010). Smallholder agriculture in East Africa: Trends, constraints and opportunities. African Development Bank. Working Paper No. 105.
Sinja J, Karugia J, Baltenweck I, Waithaka M, Miano MD, Nyikal R, Romney D (2004). Farmer perception of technology and its impacts on technology uptake: The case of fodder legume in Central Kenya Highlands. In: Shaping the future of African Agriculture for Development - The role of social scientist. Proceedings of the Inaugural Symposium of the African Association of Agricultural Economists, Grand Regency Hotel, Nairobi, Kenya, December 6-8, 2004.
Sofoluwe NA, Tijani AA, Baruwa OI (2011). Farmers' perception and adaptation to climate change in Osun State, Nigeria. Afr. J. Agric. Res. 6 (20):4789-4794.
Spann TM, Schumann AW (2010). Mineral nutrition contributes to plant diseases and pest resistance. Horticultural Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Document HS1181. https://edis.ifas.ufl.edu/hs1181.
Staver C (2002). Farmer learning linked to ecological processes for pest management: Challenges: Challenges to CATIE and its partners. Revista MIP Agroecologia 65:21-33.
Tinzaara W, Gold CS, Ssekiwoko F, Tushemereirwe W, Bandyopadhyay R, Abera A, Eden-Green SJ (2006). The possible role of insects in the transmission of banana Xanthomonas wilt. Afr. Crop Sci. J. 14:105-110.
Tripathi L, Mwangi M, Abele S, Aritua V, Tushemereirwe WK, Bandyopadhyay R (2009). Xanthomonas wilt: A threat to banana production in East and Central Africa. Plant Dis. 93(50):440-451.
Tushemereirwe WK, Holderness M, Gold CS, Deadman M (2000). Effects of the leaf spot complex and leaf pruning on growth and yield in highland bananas: Results of the first ratoon crop. Acta Hortic. (ISHS) 450:335-341.
Tushemereirwe WK, Kangire A, Kubiriba J, Nakyanzi M, Gold CS (2004). Diseases threatening banana biodiversity in Uganda. Afr. Crop Sci. J. 12 (1):19-26.
University of Minnesota / Extension (2000). Manure management: soil scientist. Regents of University of Minnesota. WW-07401.
Van Asten PJA, Wairegi LWI, Bagamba F, Drew C (2010). Factors driving fertilizer adoption in banana (Musa spp) systems in Uganda. Acta Hortic. (ISHS) 879:465-477.
Vargas, A., Araya M., Guzman M., Murillo G. (2009). Effect of leaf pruning at flower emergence of banana plants (Musa AAA) on fruit yield and black Sigatoka (Mycosphaerella fijiensis) disease. Int. J. Pest Manage. 5:19-25.
Wezel A, Bellon S, Dore T, Francis C, Vallod D, David C (2009). Agroecology as a science, a movement and a practice. A review. Agron. Sustain. Dev. 29: 503-515. DOI:10.1051/agro/2009004
Woodley E (2004). Local and indigenous ecological knowledge as an emergent property of a complex system: A case study in the Solomon Islands. Paper prepared for the Millennium Ecosystem Assessment Conference "Bridging Scales and Epistemologies", 17-20 March 2004. Alexandria, Egypt.
World Bank (2007a). World Development Report 2008. Agriculture for development. Washington D.C.