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Diversity of cultural practices used in banana plantations and possibilities for fine-tuning: Case of North Kivu and Ituri provinces, eastern Democratic Republic of Congo

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Diverse cultural practices have been communicated to and/or applied by resource-poor households over the past two decades to improve the overall farm health and crop tolerance to biotic/abiotic factors. This study assessed the current diversity and use of cultural practices on banana fields in Ituri and North Kivu provinces, eastern Democratic Republic of Congo (DR Congo). Interview schedules coupled with farm diagnosis were used to take stock of cultural practices. Farmers' choice of banana cultivars was mainly influenced by bunch size, demand/price, pulp flavor/taste, and juice quality. Availability of planting materials and the lifespan of mats were also important. In contrast, drought tolerance, soil fertility conditions, length of production cycle, and pest and disease resistance were not highly considered. Suckers were the predominant type of planting material used. Banana-bean (in 15 to 39% of farms) and banana-taro-bean (18 to 30%) were the dominant intercrops. Staking of banana plants with bunches was applied by 94 to 95% of the respondents, possibly due to the perceived immediate benefits from bunches. Cutting of green leaves to among other things improve sunlight penetration for legume intercrops which was practiced by 74 to 85% of the farmers. This practice has greatly contributed to the perpetuation of banana Xanthomonas wilt disease (XW) in the region. Male bud removal was applied in 55 to 66% of farms to control XW and improve bunch size. However, 38 to 51% of these farmers de-budded after the recommended time. Other common cultural practices included de-suckering, pseudostem use for mulch and weeding. Strategies for safe application of some of the practices such as weeding, leaf cutting, de-trashing and in light of diseases such as XW are recommended. In addition, some practices such as mulching and male bud removal are knowledge intensive, while others such de-suckering have no immediate perceived benefits to farmers, thus the need to strengthen knowledge extension to enhance their adoption.

Key words: Cropping, cultivars, cultural practices, de-budding, de-leafing, de-suckering.

INTRODUCTION

Musa species (banana and plantain, here after referred to as banana) constitute the staple food available all year round for the population of eastern Democratic Republic of Congo (DR Congo) with consumption per inhabitant of about 200 kg/year (Ndungo et al., 2004). The eastern provinces of DR Congo produce a staggering 70% of the banana and plantain crop, with 24% produced in North Kivu province (Bakelana and Ndungo, 2004). However, the area planted to banana and plantain, and yield per unit area have declined over the past decades by 20 to 60% (Mobambo et al., 2010) even though demand remains high, leading to high market prices that are beyond the reach of poor urban households (Bakelana and Ndungo, 2004).

The decline in banana production and productivity is attributed mainly to the increased burden of pests and diseases (Vuylsteke, 1993). Xanthomonas wilt of banana (XW) and Banana Bunchy Top Disease (BBTD) are the two most important banana diseases threatening food security in DR Congo. There are no known resistant cultivars to these diseases in the east and central African region (Smith et al., 1998; Tripathi et al., 2008). Cultural practices improve the overall farm health and are the main affordable options available to the resource poor households for mitigating crop losses due to pests and diseases and for maintaining soil fertility. Nicholls and Altieri (2005) reported that agroecosystem health can be optimized through habitat manipulation and soil fertility enhancement. Several cultural practices on the banana farms focus at manipulating the crop or crop environment, thus improving its ability to withstand stresses in its environment. For example, cultural practices, including early de-budding, disinfection of garden tools, removal of infected mats, cutting of single diseased plants in mats and banana free fallows are some of the recommended control measures for the control of XW (Turyagyenda et al., 2008; Sivirihauma et al., 2013; Blomme et al., 2014). Similarly, cultural practices such as identifying and destroying virus-infected plants/mats as early as possible, replanting with virus-free plants are recommended strategies for controlling BBTV (Robson et al., 2007; Niyongere et al., 2012).

Practices that replenish and maintain high soil organic matter and enhance the level and diversity of soil macro and microbiota create an environment that enhances plant health, reducing crop losses due to insect pests and diseases (McGuiness et al., 1993; Altieri and Nicholls, 2003). In contrast, farming practices that cause plant nutrition imbalances can lower crop resistance to pests and diseases (Magdoff and van Es, 2000). Cultural practices that improve soil fertility include, but not limited to, crop rotation, mulching, use of organic manure and crop diversification for example through intercropping (Lampkin, 1990; Magdoff and van Es, 2000).

Despite the potential of agronomic practices to reduce pest and disease pressures, improve soil conditions and crop tolerance, their application especially among resource poor farmers in east and central Africa is limited. Ocimati et al. (2013) emphasized the need to strengthen knowledge extension to farmers in banana growing zones of Burundi, Rwanda and eastern DR Congo. For example, Ocimati et al. (2013) observed that the use of clean planting materials was not highly adopted, with most farmers using suckers from their own or neighboring farms. They also noted that, some of the recommended agronomic practices, such as de-trashing (that is, removal of old leaves), de-suckering (that is, removal of excess suckers), de-budding (that is, removal of the male inflorescence part) and weeding, need to be revised/adapted in the face of new and emerging challenges, especially those from diseases such as XW. Agroforestry and fallowing were not widely applied due to an increased pressure on the land arising from a high human population density in this region and the perennial nature of the banana crop. Table 1 gives a summary of examples of different cultural practices and how they impact on banana yields, soil fertility/erosion, pest and disease incidence level. The assumption is that if widely and properly applied, the cultural practices can improve banana productivity in these regions. This study built on Ocimati et al. (2013). It assessed the adoption and use of different recommended agronomic practices for optimizing banana yield and production in Ituri province and parts of the North Kivu province, as a basis for further improvement efforts.

MATERIALS AND METHODS

Farm surveys and focus group discussions (FGD) were conducted in 2011/2012 in North Kivu and Ituri provinces in the eastern DR Congo. This study covered 8 territories, 5 from Ituri province (Aru, Djugu, Irumu, Mahagi, and Mambasa) and 3 from North Kivu province (Beni, Lubero, Rutshuru). A total of three villages in which bananas play an important income and food security role were purposively sampled per territory with the help of local agronomists, resulting in a total of 24 villages across the eight territories. In each village, two focus group discussions consisting of 20 men and 20 women were separately conducted to obtain a quick impression of the cultural practices applied on the banana farms. Women and men were separated to encourage greater participation

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Table 1. The links between cultural practices with soil factors, pests and diseases and banana crop management. Stars ('*') denote the ease with which the cultural practice can be applied. The more the stars, the easier it is for the practice to be applied.

Cultural practice	Importance in disease, pest, soil and crop management	Possible negative effect/ limitations	Ease of applicability under small-scale farmer conditions
De-budding using a forked stick	Increases bunch size (Tushemereirwe et al., 2001), reduces sites for insect vector transfer of bacterial and fungal infections such as XW, Bugtok and Moko disease caused by *Ralstonia solanacearum,* blood disease caused by *Pseudomonas celebensis*; and cigar end rot caused by either *Verticillium theobromae, Trachsphaera fructigena* and/or *Gloeosporium musarum* (Tushemereirwe et al., 2001; Blomme et al., 2005; Molina, 2006)	De-budding using metal farm tools can increase XW infections if tools are not sterilized between plants/successive cuts.	*****
Mulching	Improves moisture retention, reduces weed growth and enhances soil fertility and microbial activity thus improving plant growth and yield	Access to mulch often limiting	*
Staking/ propping	Prevents snapping/doubling/toppling of plants under the weight of the bunches (Tushemereirwe et al., 2001)	Staking material may be limiting	***
De-trashing	Minimizes black leaf streak/black sigatoka spread to young leaves and plants from old diseased or dry leaves. Improves light penetration for intercrops, air flow reducing risk of fungal infections (Tushemereirwe et al., 2001)	Cutting leaves that are still fresh/green possess the risk of spreading XW within the farm (Addis et al., 2010; Ocimati et al., 2013)	****
Weeding	Reduces competition for water and nutrients, improves soil drainage and aeration, helps to incorporate manure	Weeding with tools in the presence of XW could lead to within field spread of the disease	***
De-suckering	Reduces competition for light, water and nutrients – leading to more vigorous plant growth and bigger bunches (Tushemereirwe et al., 2001)	Failure to sterilize tools between mats could lead to the spread of XW if present in the field	**
Leaf cutting	To increase level of sun light penetration for annual intercrops	Poses the risk of spread of bacterial diseases (XW, Moko, Bugtok, Blood disease). If done extensively could affect the photosynthetic capacity of the plant.	****
Manure application	Improves organic matter content, soil fertility and properties	Access to livestock is limiting	*
Selection of planting material	Clean, disease/pest-free and vigorous planting materials improve yields	Use of suckers increases the risk of spread of banana pests and diseases. Build-up of pest and diseases occurs with repeated use of suckers from own or neighboring fields.	**
Inter-cropping	If well managed improves resilience of the soils/cropping system and improves plot yields	Inter-cropping with annual crops increases risk of XW spread. Could increase competition for nutrients water and light if not well managed	***

Table 1. Contd.

Banana agroforestry practices	Increases total farm productivity. While intercropped with some tree species e.g. with Arabica coffee higher coffee and banana yields were reported (van Asten et al., 2011).	Could increase competition for nutrients water and light if not well managed e.g. intercropping banana with Robusta coffee negatively impacts on banana yield (van Asten et al., 2011).	*
Fallowing	Recommended for breaking the disease cycle especially for XW and BBTD. Can also help in the control of banana pests, e.g. the banana weevil and nematodes. Not practiced with the objective of improving soil conditions due to the perennial nature of the crop	Care should be taken to remove all corm bits and alternative hosts while fallowing to control pests and diseases. Has been limited due to high population density and land shortage	*
Planting spacing	Varies with mono and intercrops. 3 m by 3 m is the most widely recommended	Where intercropping is inevitable, this spacing often leads to shading of annual crops and leaf cutting	*****
Leaf bending	Recommended in fields were XW is present. Recommended in intercropped fields instead of leaf cutting. The bent leaves can still continue to some degree with photosynthesis (Blomme et al., 2017).	Could possibly increase black leaf streak incidence/severity on younger leaves.	*****

in each group.

The FGD were followed by field diagnostic surveys. A total of 10 farms/households having at least 20 mats per plot/farm of banana/plantain were selected per village, totaling 240 farms for this household survey using a questionnaire (Figure 1). The questionnaire determined the typologies of the banana cropping systems and the key cultural practices on the banana farms. The questionnaire for example ranked nine criteria that could be used by farmers to select banana cultivar types to grow. The nine criteria included: (i) the availability of planting materials, (ii) bunch size, (iii) tolerance to infertile soils, (iv) drought tolerance, (v) good pulp flavor, taste and juice quality, (vi) long mat lifespan, (vii) high market demand and prices, (viii) short production cycle and (ix) resistance to pest and diseases. Other cultural practices such as de-suckering, de-leafing, de-budding, mulching and manuring were also assessed.

Geographical positions of the sampled farms were recorded using a GPS (Etrex) device at a precision of ±3 m and used to generate a map (Figure 1). Data were cleaned, coded and the SPSS software used to generate descriptive statistics for different cultural practices obtained across the study sites. Chi-square tests were used to compare means for the different cultural practices between the North Kivu and Ituri province sites at $P < 0.05$.

RESULTS

Farmer selection criteria for banana cultivars, type and origin of planting material

Similar trends in farmer's criteria for selection of cultivars to grow were observed in both North Kivu and Ituri provinces (Figures 2 and 3). Across the study sites, farmers ranked bunch size, pulp/juice flavor/taste/quality and the market price of bunches highest out of nine possible banana cultivar selection criteria presented to them. Other important criteria included the availability of planting materials and the lifespan of the mats for a cultivar. Soil fertility and drought tolerance and resistance to diseases were not highly ranked in both study sites (Figures 2 and 3).

No significant differences ($P>0.05$) were observed between the two provinces for the period of selecting banana planting materials, the responsibility of selecting planting materials within the household, type, and source of planting materials. Planting materials were selected by most farmers at the beginning of the rainy season in September in both North Kivu (58%) and Ituri provinces (62%) while the other farmers were not conscious of the timing. This task was, in over 83% of cases undertaken by the heads of the households (predominantly male) in both sites (Table 2).

All of the farmers across the study sites used suckers as planting material (Table 2). These planting materials come mainly from neighboring farmers' fields. A small proportion (1 to 3%) of the farmers obtain planting materials from either their own farms or from Uganda, the neighboring country.

Banana cropping systems

Most farmers across North Kivu (61%) and Ituri provinces

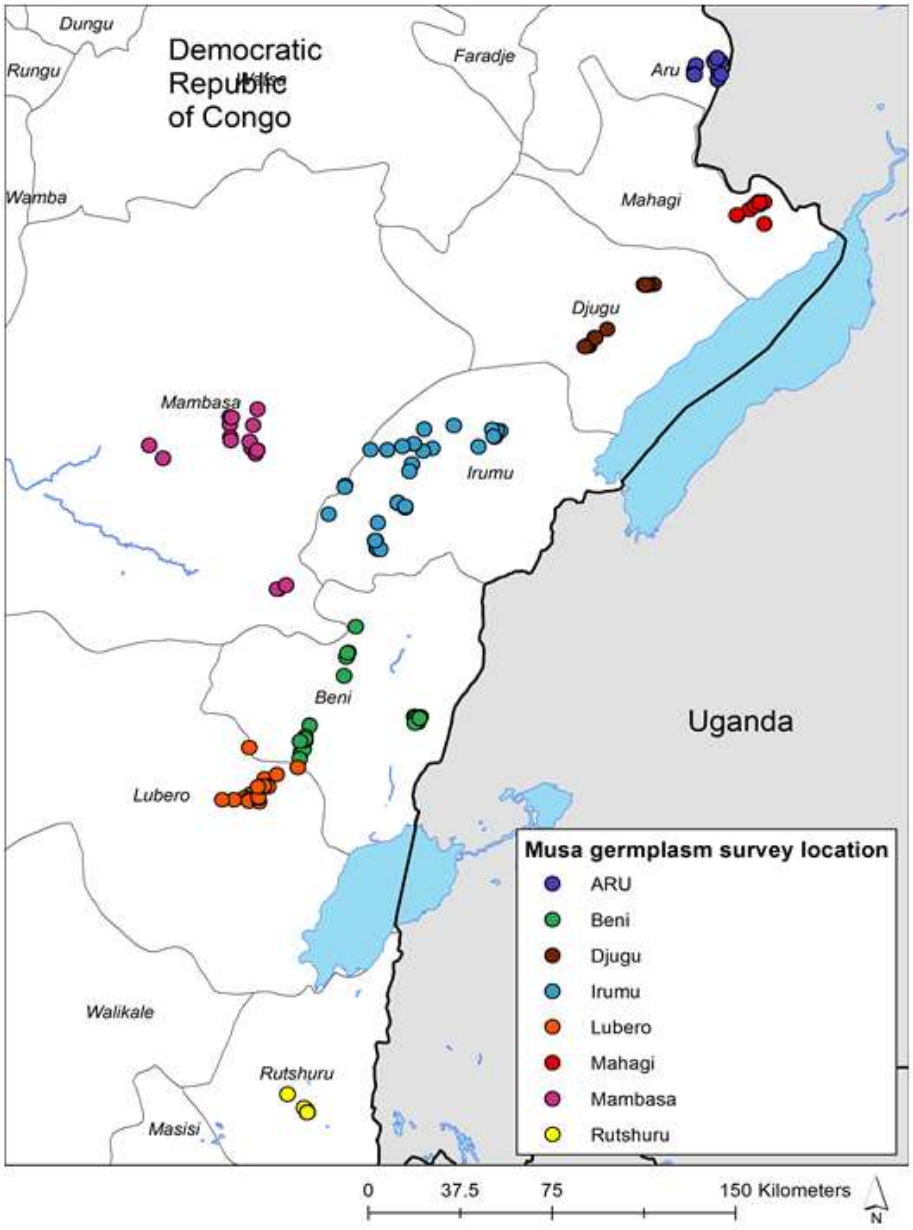

Figure 1. Survey locations across Ituri and North Kivu Provinces in eastern DR Congo.

(52%) practiced intercropping compared to 39 and 48%, respectively, who planted banana as a mono-crop. More farmers in North Kivu province intercropped banana compared to Ituri province (Table 3). However, no significant differences (P>0.05) were observed between the two sites in the proportions of farmers who either intercropped or mono-cropped banana.

Only between 14 and 18%, respectively, in North Kivu and Ituri provinces practiced agroforestry on their farms. In most of the cases (89 to 92%), farmers had scattered trees within their banana farms. No significant differences (P>0.05) in agroforestry practices were observed between the two sites (Table 3).

Eighteen and 14 different banana-other crop (annual and perennial) or banana-tree associations were found in Ituri and North Kivu provinces respectively. Among the different types of inter-cropping systems, the most commonly practiced in both Ituri and North-Kivu provinces included banana-bean (15 and 39%), banana-bean-taro (18 and 30%), banana-maize-bean (2 and 14%) and banana-coffee (7 and 5%) intercrops (Table 3). Significant differences (P<0.05) in the combinations of cropping mixtures were visible between the two provinces.

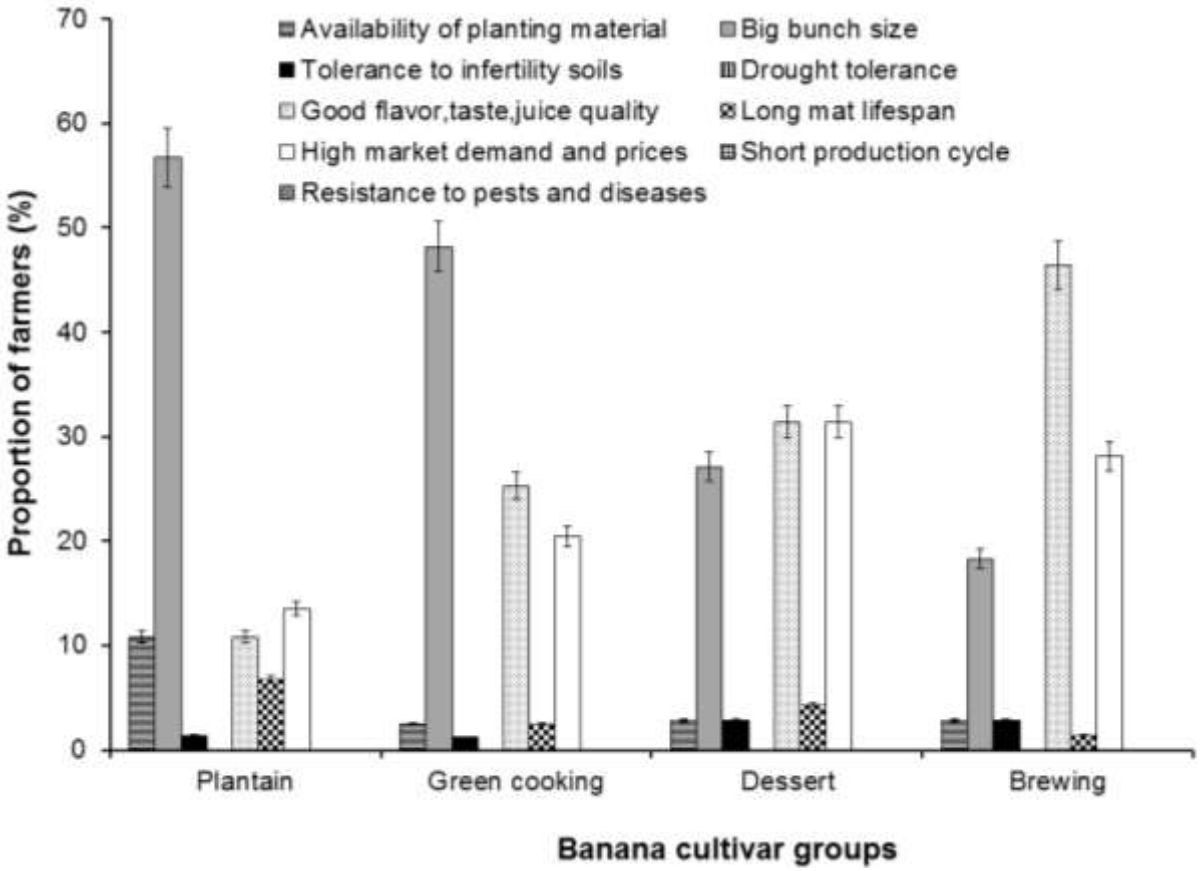

Figure 2. Farmer rankings for different criteria they consider for when selecting/ chosing cultivars in different use groups to grow in North Kivu, eastern DR Congo. Error bars denote 95% Co-efficient Interval.

De-suckering of banana mats

Sixty nine percent of the farmers in both Ituri and North Kivu provinces applied the technique of de-suckering, mainly to (i) decrease interplant competition and hence increase bunch sizes, (ii) obtain suckers for establishing new banana plots/fields and (iii) to maintain their fields tidy. The majority of farmers (between 53 and 57%) de-suckered when it was necessary, while 42 to 41% at the onset of the rainy season at the beginning of September/ October (Table 4). The number of suckers maintained varied between 3 and 5 per banana mat. No significant differences occurred in the de-suckering practices between North Kivu and Ituri provinces.

A minority of farmers (31%) did not apply de-suckering on their farms. In North Kivu this was mainly because the plantations were old and less productive (45% of farmers) to warrant further investment, while it was due to lack of time (that is, competed with other farm activities) in Ituri province (61%). Between 26 and 28% did not de-sucker because it was cumbersome (Table 4). Significant differences ($P<0.05$) were observed between the two sites for the reasons cited by the farmers not de-suckering their farms.

De-leafing and de-budding

Eighty five percent of the farmers in North Kivu and 74% in Ituri province cut off fresh green banana leaves (de-leafing) in their plantations. The green leaves were mainly cut to maintain banana plantations clean, to obtain mulch material and to decrease shade and allow in sunlight for the intercrops, especially beans (Table 5). Most farmers (62 to 65%) cut leaves when they found it necessary, while a good proportion (34 to 38%) cut leaves at the onset of the rainy season, corresponding with the time of planting annual crops. Significantly, more farmers ($P<0.001$) cut leaves as a field maintenance practice in Ituri province, while more cut leaves to allow light for intercropped annual crops in North Kivu. For the purpose of reducing shading, most farmers maintained between 4 and 6 leaves on each banana plant (Table 5). Those that did not de-leaf and de-trash attributed it to lack of time for this practice.

De-budding (removal of the male buds) is a more

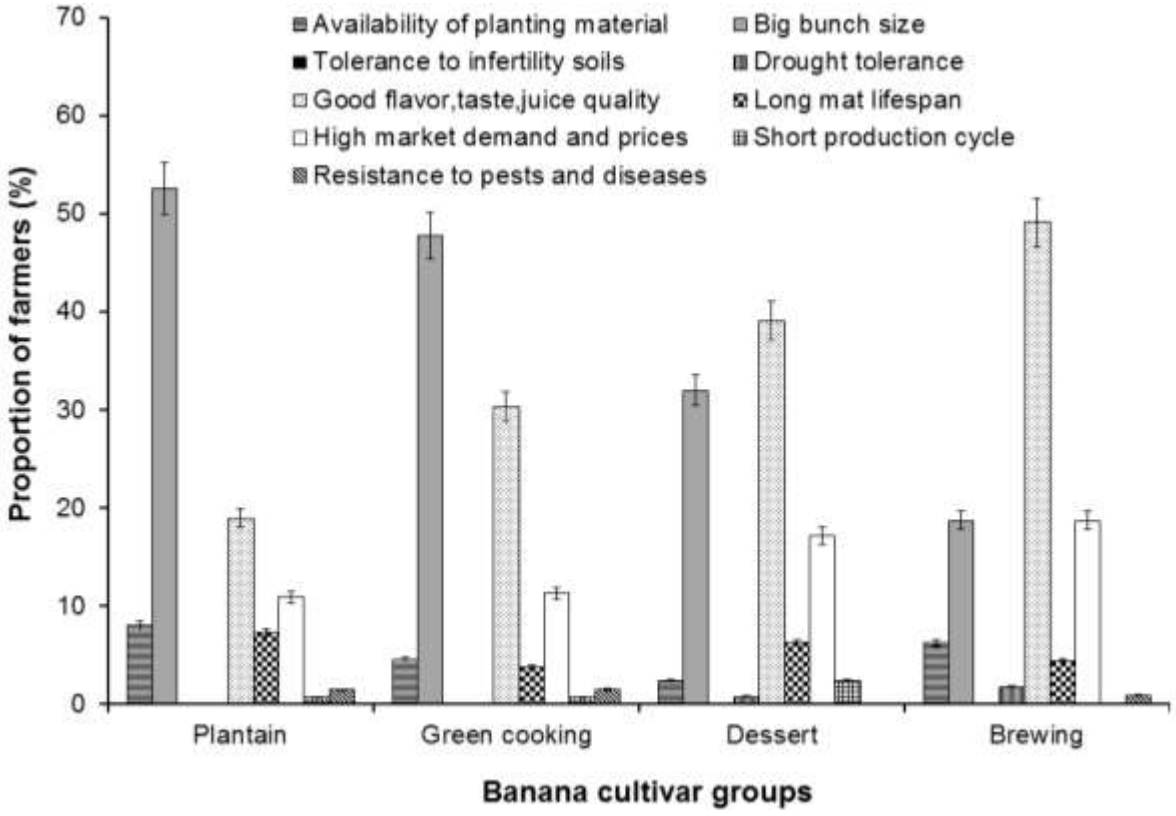

Figure 3. Farmer rankings for different criteria they consider when selecting/ chosing cultivars in different use groups to grow in Ituri Province, eastern DR Congo. Error bars denote the 95% Co-efficient Interval.

common practice in North Kivu (66% of farms) than Ituri province (56%) (Table 5) despite no significant difference ($P<0.05$) was observed between the two sites. The major reason behind de-budding was to prevent spread of diseases, especially XW disease that is prevalent in the study sites (Table 5). A smaller proportion (12 to 33%) of farmers de-budded to increase the bunch size. Significant differences ($P<0.01$) in the objectives of de-budding were recorded between the two sites, with more farmers (88%) de-budding to manage diseases in North Kivu compared to 67% in Ituri province. In contrast, more farmers (33%) in Ituri province compared to 12% in North Kivu de-budded to increase bunch size. Farmers who did not de-bud solely attributed it to the lack of time for the practice. Timely de-budding with a forked stick to minimize access to the male inflorescence by insect vectors of *Xanthomonas campestris* pv. *musacearum* is one of the control options for banana bacterial wilt (Brandt et al., 1997). However, a good proportion of farmers, 51% in North Kivu and 38% in Ituri did not timely de-bud their plants (Table 5).

Staking, use of harvested pseudostems and weeding

The technique of staking (supporting of banana plants) is applied by the majority of farmers surveyed (at least 94% of farmers in Ituri and North Kivu). Staking is mainly practiced in order to prevent lodging/toppling/snapping/ doubling of banana plants caused by either the heavy weight of bunches or wind. A total of 58 and 59% of the farmers in North Kivu and Ituri, respectively staked their plants whenever they found it necessary, while 36 to 39% and 3 to 4% across sites staked plants during bunch filling and at flowering (that is, at specific plant growth stages), respectively (Table 6).

Regarding the use of pseudostems after harvesting, 85 and 91% of farmers in Ituri and North Kivu provinces, respectively, cut them into small pieces for use as mulch material. A minority of farmers (2 to 4%) use it for feeding livestock, while others left them standing (7 to 11%).

Weeding was mainly (96 and 94% in North Kivu and Ituri, respectively) performed using a hand hoe. 12 and 21% of farmers in North Kivu and Ituri, respectively, cut down weeds using machetes (Table 6). Herbicide use to kill weeds was not practiced across the sites.

DISCUSSION

This study assessed the diversity and use of cultural practices in banana plantations in Ituri and North Kivu

Table 2. Planting material attributes, across the study sites in Ituri and North Kivu provinces in eastern DR Congo.

Attributes		North Kivu (n=90)	Ituri (n=150)	χ^2-test
Period of selection of planting material	Beginning of the rainy season	58	62	0.369^{ns}
	Any time	42	38	
	Total (%)	100	100	
Who selects the planting material?	Head of household	90	83	2.491^{ns}
	All household members	10	17	
	Total (%)	100	100	
Type of planting material used	Suckers	100	100.0	^{ns}
	In-vitro plantlets	0.0	0.0	
	Corm/corm piece	0.0	0.0	
	Macro-propagation plantlets	1.1	0.0	
Source of planting materials	Neighbor	96	98	1.193^{ns}
	Own field	1	1	
	Neighboring country, that is, Uganda	3	1	
	Research institution	0.0	0.0	
	Total (%)	100	100	

'ns' denote no significant difference at P<0.05) for a given practice between the two study sites.

provinces, eastern DR Congo. Agronomic practices are often knowledge intensive and yet influence the severity of biotic and abiotic stresses and the production of banana plantations. The study showed a low variability in agronomic practices used and their application within and between sites. Agronomic practices with perceived immediate benefits tended to be widely applied. The study suggests that slight changes are needed to a few practices to achieve good management of XW disease.

The choice of cultivars grown was mainly influenced by their food attributes (taste, flavour and quality) and ability to fetch higher incomes (influenced by bunch size, market demand and prices, and food attributes). Banana and plantains in these regions are important for food and income. The market price for the bunch of a cultivar is based on its size and taste. Availability of planting materials and the lifespan of banana mats were also important. This could be a reflection of farmers need for cultivars with inexhaustible ability to produce suckers. For example, a poor suckering ability has been reported in plantains at the low altitude sites (Sikyolo et al., 2013) despite being conducive for plantain production. Demand for planting materials has also been increased by disease outbreaks, more recently the banana XW disease that has affected swathes of areas. Clean planting materials are currently needed for re-establishment of destroyed fields. Soil fertility and drought tolerance were not perceived important by farmers in the study area. The eastern DR Congo highlands are characterized by fertile soils and a good level of rainfall; as such these criteria may not be listed as priority concerns for farmers. In earlier studies in eastern DR Congo (Ocimati et al., 2013) observed that farmers maintained more suckers than recommended due to the relatively good soil fertility conditions that could support larger number of plants per mat without compromising bunch yield.

Pest and disease resistance was also not perceived as important in the study regions. It was expected that farmers would rank resistance to pest and diseases highly in this region, especially due to the presence of XW which is currently the most important constraint to banana production (Ndungo et al., 2008). Ocimati et al. (2016) reported that diseases had greatly contributed to *Musa* genetic erosion and the diversity trends in eastern DR Congo with Fusarium wilt decimating the AAB dessert and ABB beer bananas, while XW affecting all banana types, with ABB beer type 'Pisang Awak' the most affected cultivar. The observed response could be attributed to the fact that all cultivars in region are susceptible to XW and most farmers are resigned to the disease. For example, several farmers attribute the disease to a curse from God and others to a soil infection as such with no ultimate control (Ocimati W. personal communication). To address such misconceptions, knowledge extension on the epidemiology of the disease is needed.

Cultivar selection was mostly the responsibility of the male household heads. This could be linked to the fact that there is distribution of agricultural work between genders with men mostly occupied with land preparation,

Table 3. Frequency (%) of farms practicing different intercropping and agro-forestry practices in the banana-based systems across the study sites in Ituri and North Kivu provinces in eastern DR Congo. Dash (-) denotes that the cropping system is missing.

Farming system applied	**North Kivu (n=90)**	**Ituri (n=149)**	**X^2-test**
Monoculture	39	48	1.745^{ns}
Intercropping	61	52	
Agro-forestry	14	18	0.494^{ns}
Agro-forestry systems applied	**North Kivu (n=14)**	**Ituri (n=27)**	**χ^2-test**
Alley cropping	7	0	
Leaving hedge (grasses)	0	7	3.5^{ns}
Scattered trees within the plantation	92	89	
Hedge of multipurpose trees	-	4	
Crop/Tree combinations	**North Kivu (n=57)**	**Ituri (n=78)**	**χ^2-test**
Banana-beans	39	15	
Banana-beans-taro	30	18	
Banana-taro	4	-	
Banana-coffee	7	5	
Banana-maize-beans	2	14	
Banana-cassava-beans	2	-	
Banana-cocoa	2	-	
Banana-cocoa-oil palm trees	4	3	
Banana-beans-taro-cassava	2	4	
Banana-eucalyptus-avocado	-	4	
Banana-coffee-beans	4	6	
Banana-taro-maize	2	4	37.833*
Banana-sweet potatoes-taro-maize	-	4	
Banana-beans-maize-cassava	-	1	
Banana-cassava-sugarcane-oil palm trees	-	3	
Banana-sugarcane-taro- -cassava	2	4	
Banana-taro-oil palm trees	2	3	
Banana-leek-chives	-	1	
Banana-citrus trees-mango tree-coffee	2	-	
Banana-soybean-maize	-	4	
Banana-pineapple-beans-soybean	-	1	
Banana-bean-groundnuts	-	5	
Total	100	100	

'ns' and '*' respectively denote no significant and a significant difference at P<0.05) for a given practice between the two study sites.

material, while women are mostly involved in secondary activities such as weeding, harvesting, transportation and processing of banana. Ochieng et al. (2014) observed that despite the existence of gender neutrality for both banana cultivation and harvesting in parts of eastern DR Congo, banana cultivation was mainly male dominated while women mainly dominated in the production of annual crops such as sweet potato, cassava, beans, groundnuts, peas and soybeans. Ochieng et al. (2014) also reported male dominance in farm decision making in this region despite the dominance of women in agricultural activities. Similarly, Enete and Amusa (2010) reported male dominance in farm decision making functions in Nigeria even where women are the largest providers of farm labor.

Planting materials were mainly selected at the onset of the rainy season. This can be attributed to the absolute reliance on suckers picked from own or neighboring fields

Table 4. Frequency (%) of farmers de-suckering or not de-suckering, de-suckering at different times and the number of suckers they maintain on a banana mat across the study sites in Ituri(I) and North Kivu (NK) provinces in eastern DR Congo.

Parameter		NK	I	χ^2-test
De-suckering (n=90 in NK; n=150 in I)	Yes	69	69	0.005^{ns}
	No	31	31	
	Total	100	100	
Reasons for de-suckering (n=62 in NK; n=104 in I)	To increase bunch size	54	37	5.413^{ns}
	To obtain suckers for establishing new mats/fields	36	52	
	For routine field maintenance	10	12	
	Total	100	100	
Reasons for not de-suckering (n=31 in NK; n=46 in I)	Time constraint	29	61	13.476**
	De-suckering is cumbersome	26	28	
	The plantation is old	45	11	
	Total	100	100	
Number of suckers maintained on a mat (n=65 in NK: n=105 in I)	3	34	30	0.410^{ns}
	3-4	33	34	
	4	23	25	
	4-5	10	10	
	Total	100	100	
Time of de-suckering (n=52 in NK; n=101 in I)	Beginning of the rainy season	42	44	1.244^{ns}
	Middle of the rainy season	2	3	
	Any time	57	53	
	Total	100	100	

'ns' and '**' respectively denote no significant at P<0.05 and a significant difference at P<0.01 for the given practice between the two study sites.

that does not require prior preparation. In addition, banana production is entirely rain fed. Reliance on suckers from farmers' own and neighbors' farms in eastern DR Congo has been attributed to the lack of capacity for the production of clean planting material through field sucker multiplication plots, macro-propagation and micro-propagation (Ocimati et al., 2013). Dependency on suckers results in a high risk of pest (e.g. banana weevil and nematodes) and disease (e.g. Xanthomonas wilt of banana, Fusarium wilt, banana bunchy top disease and the banana streak virus) transmission, especially when recommended cultural practices (such as the selection of healthy suckers from clean mother gardens, corm paring and/or boiling water treatment to remove weevil larvae and parasitic nematodes) are not applied (FAO, 2010). For example, the dependency on suckers from own or neighboring farms have been reported to have greatly contributed to the spread of XW in eastern DR Congo (Ndungo et al., 2008). It is often difficult to distinguish between healthy suckers and those apparently healthy especially for XW, BBTD and nematodes which are living inside roots. A minority of farmers (1%) in the province of North Kivu use macro-propagated plantlets, a technology that was disseminated by the Consortium for Improving Agriculture-based Livelihoods in Central Africa (CIALCA) in this part of the country. In addition to the lack of capacities to produce clean planting material, the cost of macro-propagated and tissue culture-derived plantlets (~$1) compared to $0 to 0.25 for suckers are high and out of reach for most farmers. Building capacities for clean seed production (e.g., clean mother gardens, macro-propagation) coupled to promotional activities in these study regions is urgently recommended. This is postulated to improve the management of biotic constraints, aid in timely planting and ultimately the improvement of banana production.

In 39 to 48% of farms, banana was grown as a sole crop while in 52 to 61% was intercropped with a total of 14 to 18 different crop/crop and crop/tree combinations. It is important to note that the East Africa highlands have a high population density (Voortman et al., 2003) that has increased pressure on the land (Fermont et al., 2008). The associations of cultivated plants are designed to take

Table 5. Frequency (%) of farmers for different de-leafing and de-budding practices in North Kivu and Ituri provinces, eastern Democratic Republic of Congo. NK and I respectively, denote North Kivu and Ituri Provinces.

Parameter		North Kivu	Ituri	χ^2-test
Deleafing (n=90 in NK; n=150 in I)	Yes	85	74	3.823*
	No	15	26	
	Total	100	100	
Reasons for de-leafing (n=77 in NK; n=110 in I)	Maintenance of banana plantation	43	70	22.337***
	To provide mulch under banana	26	23	
	Cover banana bunches to enhance ripening	12	1	
	Provide light to beans	19	6	
	Total	100	100	
Timing of de-leafing (n=77 in NK; n=110 in I)	Beginning of the rainy season	38	34	0.977^{ns}
	Middle of the rainy season	0	1	
	Any time	62	65	
De-budding (n=90 in NK; n=150 in I)	Proportion who de-bud	66	56	2.455^{ns}
Reasons for de-budding (n=59 in NK; n=83 in I)	De-bud to manage disease	88	67	8.364**
	De-bud to increase bunch size	12	33	
Time of de-budding (n=63 in NK; n=84 in I)	After emergence of the last hand	49	62	2.015^{ns}
	After bunch filling	48	34	
	Any time	3	4	

'ns', '*', '**' and '***' respectively denote no significant at P<0.05, a significant difference at P<0.05, P<0.01 and P<0.001 for the given practice between the two study sites.

Table 6. Frequency (%) for staking banana plants, pseudostem uses and weeding practices by farmers in North Kivu and Ituri provinces, eastern Democratic Republic of Congo. NK and I respectively, denote North Kivu and Ituri Provinces.

Parameter		North Kivu	Ituri	χ^2-test
Staking (n=90 in NK; n=150 in I)	Proportion who stake plants	94	95	0.783^{ns}
Timing of staking (n=85 in NK; n=143 in I)	At flowering stage	3	4	1.53^{ns}
	During bunch filling	39	36	
	Just before harvest	0	1	
	Whenever it is vital	58	59	
Pseudostem use (n=90 in NK; n=150 in I)	Cut into small pieces for use as mulch	91	85	1.73^{ns}
	Leave them standing	7	11	
	Feeding livestock	2	4	
Weeding (n=90 in NK; n=150 in I)	Hand weeding	0	1	4.291^{ns}
	Weeding with the hoe	88	78	
	Weeding with a machete	4	5	
	Weeding with the hoe and machete	8	16	

'ns'- denotes no significant at P<0.05 for the given practice between the two study sites.

best advantage of the available small area of land per household (Sileshi et al., 2007; Ouma, 2009). Diversified cropping systems, such as those based on intercropping and agroforestry or cover crops, have also gained interest largely due to the emerging evidence that these systems are more stable and more resource conserving

(Vandermeer, 1995). Opportunities for coexistence and beneficial interference between species that can enhance agroecosystem sustainability have been reported with increased diversity on farm (Vandermeer, 1995). Banana-bean, banana-bean-taro and banana-coffee were the commonest intercrops in the study regions. Annual intercrops were often planted at the beginning of the raining season. The legume banana associations benefit the banana crop through nitrogen fixation and by controlling erosion. However, this practice involves tilling within the banana plantations which damages the superficial roots of banana plants and could potentially promote the spread of Xanthomonas wilt of banana, Fusarium wilt and nematodes. The practice of mulching of banana plots in combination with zero tillage and the use of a piece of wood for planting e.g. beans could be explored to prevent root damage and limit the risk of infections. The currently most widely recommended banana mat spacing in East and Central Africa is 3 × 3 m (Tushemereirwe et al., 2001). Studies to determine the optimum spacing for banana-annual crop intercropping with minimal interference from the banana crop or the intercrop are thus necessary.

De-suckering helps to maintain the chosen plant density thus reducing competition for available resources (Tushemereirwe et al., 2001). Most farmers (69%) practiced de-suckering across North Kivu and Ituri provinces. A slightly lower number of farmers (65%) were observed to de-sucker in North Kivu in an earlier study by Ocimati et al. (2013), however, North Kivu ranked behind Rwanda, Burundi and the South Kivu province in eastern DR Congo. Ndungo et al. (2008) also reported that farmers in North Kivu put low effort into the management of their banana plantations. However, in the current study, and unlike in Ocimati et al. (2013) where most (over 90%) farmers de-suckered at the onset of the rains, most farmers de-suckered when necessary (that is, not linked to a specific time period). This could be a reflection of the chosen application of the practice. Similarly, most farmers maintained between 3 and 4 plants compared with 4 to 7 plants as reported by Ocimati et al. (2013). This could be attributed to intensive extension efforts spearheaded by the CIALCA project during 2007 to 2011. Nonetheless, a large number of farmers' still maintained more than the three recommended (at various growth stages-parent, child and grandchild) plants per mat (Tushemereirwe et al., 2001). Ocimati et al. (2013) reported that the maintenance of more suckers than recommended is sustained by the high soil fertility conditions in the study region that can still support a large number of plants per mat without compromising the yield per unit area.

Cutting of green leaves (de-leafing) was common in 74 to 85% of farms. Apart from their use for domestic purposes, leaves were mainly cut to maintain the field and reduce shading at the onset of the rains when intercrops especially, legumes were planted. Intercropping bananas is a common practice mainly resulting from the high population density and the limited access to land (Ocimati et al., 2013; Fermont et al., 2008). Despite the potential benefits of intercropping (such as nitrogen fixation, pest suppression, soil erosion control) leaf cutting exposes the banana plants to XW infection through tool use. Indeed, tools are one of the most common means of XW spread in this region. Ocimati et al. (2013) recommends the removal of only the fully dried out leaves to prevent tool transmission of XW through de-leafing. In addition, cutting of leaves at bunch emergence could severely impact on bunch yields. Blomme et al. (2017) recommends leaf-bending in fields where XW is present in order to prevent disease spread because the bended leaves can potentially still carry out photosynthesis.

De-budding, practiced in 66 (North Kivu) to 56% (Ituri) of the farms was aimed at XW management (preventing insect vector transmission) and increasing bunch size. The current figure in North Kivu (66%) is slightly higher than the 62% earlier reported for North Kivu by Ocimati et al. (2013). Male bud removal as soon as the last hand in a bunch is formed has been reported to prevent the spread of XW (Blomme et al., 2005). However, most of the farmers who de-budded, either were not concerned about the time of de-budding or de-budded too late to be able to prevent a possible XW infection. Similar observations were reported by Ocimati et al. (2013). This could partially explain the continuous perpetuation of the XW problem in the study region. De-budding is also one of the measures for preventing fungal infections such as cigar end rot disease caused by *Verticillium theobromae, Trachsphaera fructigena* and/or *Gloeosporium musarum* (Mwangi, 2007). Removal of the male bud has been reported to increase the bunch weight due to an increase in finger size (Daniells et al., 1994). Daniells et al. (1994) reported that the male bud represented a significant competing photosynthetic sink. Thus, there is need to highlight the numerous benefits that accrue from the timely male bud removal so as to promote its application among the farming communities.

The technique of staking was highly applied. Staking was mainly practiced to prevent lodging/toppling/ snapping/doubling of banana plants caused by the weight of bunches. Across the sites, the harvested pseudostem was mainly used as mulch material. This practice is important for nutrients recycling, reducing water runoff and loss through evaporation and in suppressing weeds, functions that are important for the sustainable productivity of the banana farms in these regions (Ocimati et al., 2013). The importance of mulching using pseudostems in the study regions is important as the resource poor households are not able to apply other sources of mulch (e.g. grass and other crop residues) due to associated costs and limited availability.

Weeds were mainly controlled using hand hoes, while a minority used machetes to cut or slash the weeds. Hand

Table 7. Recommendations for improving the efficacy of selected cultural practices in the face of Xanthomonas wilt disease and high population densities.

Cultural practice	Recommendation
De-trashing	Only cut the dry leaves to avoid BXW spread
Weeding	Mulching suppresses weed growth, keeps the ground soft, conserves soil moisture and in combination with zero tillage could reduce the risk of BXW spread in fields
De-leafing (cutting green leaves)	Increase spacing of banana to >3 m × 3 m where inter-cropping is inevitable to minimize the need for leaf cutting to increase level of sun light penetration for annual intercrops Bend leaves (at the petiole level) using forked sticks instead of cutting. Such leaves could potentially continue to partition assimilates
Selection of planting material	Build capacities for clean seed production using simple techniques e.g. macro-propagation Increase promotional activities for the use of clean seed.
Inter-cropping	Increase spacing of banana to >3 m × 3 m to minimize shading of intercrops Identify shade tolerant crop species to plant under the banana crops
Banana-agroforestry practices	Test/Fine-tune good practices for integrating trees in banana e.g. use of tree at borders and as hedges
Planting spacing/ density	In densely populated communities and where farmers inter-crop (the case in eastern DR Congo), wider banana spacing (>3 m × 3 m) is recommended
Leaf bending	Recommended in inter-cropped or XW infected fields instead of leaf cutting. The bent leaves could still continue with photosynthesis.

hoe weeding is attributed to the need to intercrop with legumes and other annual crops. Hand weeding and herbicides were not at all used across the sites. Similar observations were reported in North Kivu by Ocimati et al. (2013).

CONCLUSION AND RECOMMENDATION

Cultural/Agronomic practices are crucial agro-ecological intensification practices for enhancing food productivity and soil/field health. However, some of the practices such as de-budding and mulching are knowledge intensive and do not have immediate perceived benefits to the farmers and thus the need to strengthen knowledge extension to farmers to enhance their adoption. Ease of applicability of the various cultural practices and their contribution to pest and disease management and productivity are listed in Table 1. In the face of severe diseases such as XW, cultural practices such as de-trashing, de-leafing and banana spacing need to be modified. Some slight modifications were suggested to the current cultural practices in Table 7 to minimize XW disease spread. For example, cutting of green banana leaves to allow for intercropping was prevalent, potentially affecting banana yields and exacerbating the XW problem. In such communities where intercropping of banana with annual crops is in-evitable, we recommend studies to revise banana spacing to enable both the intercrop and banana to co-exist with minimum interferences. The recommended changes are not cumbersome and with clear benefits, thus have a high probability of success within the communities. Capacities for clean seed production need to be urgently built. In addition, promotional activities are needed to foster clean seed use and other practices for management of biotic constraints. Regular feedbacks from extension workers could possibly contribute to timely fine-tuning of recommended cultural practices and enhance their adoption.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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