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On-farm *Musa* germplasm diversity in different agro-ecologies of Burundi

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Burundi is part of the secondary centre of diversity for the east African highland bananas (*Musa* AAA-EA). However, *Musa* diversity in Burundi has declined in the past two decades due to pests, diseases and civil unrest. A *Musa* germplasm diagnostic survey carried out in three provinces- Gitega in Central, Kirundo in Northern and Cibitoke in north-western Burundi, assessed on-farm *Musa* diversity, *Musa* selection criteria influencing *Musa* diversity and genetic erosion. *Musa* diversity was determined by the number and relative abundance of *Musa* cultivars in the study communities. Thirty-three (33) cultivars were recorded across the three provinces. Gitega and Kirundo had a higher *Musa* diversity than Cibitoke. Low *Musa* diversity in Cibitoke can be attributed to the existence of a few cultivars adapted to the low altitude; specialization in beer types for the market and the effect of diseases. Though 11 cultivars were widely grown, only four covered 77% of the Burundian banana landscape. These cultivars have a high market potential. The less common cultivars are vulnerable to genetic erosion and hence their conservation is recommended. Flavour, pulp taste and juice quality; and market demand/prices greatly influenced cultivars maintained on farm. 30% of the respondents experienced cultivar erosion, with 69% reporting loss in Cibitoke, 29% in Kirundo and 19% in Gitega. Diseases (89%) were the major cause of this loss. 'Kamaramasenge' (AAB), 'Igisubi' (ABB) and 'Pisang awak' (ABB), respectively were the most affected cultivars. Banana bunchy top disease indiscriminately affects *Musa* cultivars in the low altitude regions, while the AAB dessert types and the ABB beer types are affected by Fusarium wilt. The high disease burden at low altitudes could partially be responsible for the low *Musa* diversity in Cibitoke.

Key words: Cultivar diversity, cultivar evenness;,genetic erosion, *Musa* germplasm.

INTRODUCTION

Banana and plantain (*Musa* spp.) are important staple and income-generating fruit crops for millions of people in the tropical and subtropical regions of the world (Ssebuliba et al., 2005; Robinson and Galán Saúco, 2010). In Burundi, banana plays a key role in contributing to rural household food security and revenue. The

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country is among the 20 leading banana producers in the world, with annual production estimated at 1.75 million metric tons (FAOSTAT, 2008). The crop ranks first in overall food production, followed by sweet potatoes and cassava (Anonymous, 1983). Approximately 17% of the agricultural land is devoted to banana production. The crop additionally offers an ecological advantage of protecting the ground against erosion by means of its large leaves, root system that holds the soil together and rotting leaves and trunks that add humus to the soil (Baragengana, 1985; Rishirumuhirwa and Roose, 1998). For example, much lower (30%) soil erosion levels have been reported under the permanent banana canopy than in annual cropped fields (Lufafa et al., 2003).

Burundi is one of the secondary centres of diversity for east African highland bananas (Karamura et al., 2004). The crop is grown everywhere except above 1800 m altitude (the Zaire-Nile Crest), a zone that is very small in relation to the rest of the country (Baragengana, 1985). Cooking and beer bananas are the main types grown (Spilsbury et al., 2004). Yield declines in banana have been reported in the east African region, Burundi inclusive, during the past decades (Rishirumuhirwa, 1997; Baijukya and de Steenhuijsen Piters, 1998; Woomer et al., 1998; Karamura et al., 2004). Rudebjer et al. (2011) stress the importance of monitoring trends of agrobiodiversity at three levels: ecosystem, species and intraspecific diversity in devising conservation strategies to avoid genetic erosion and for planning sustainable management of these genetic resources. However, little is known of the *Musa* germplasm diversity status in Burundi. Just like in neighbouring Rwanda were *Musa* production and germplasm diversity has been reported to decline in the last ten to twenty years due to land pressure, pests, diseases, plant nutritional problems and the 1994 genocide (Okech et al., 2005; Nsabimana and van Staden, 2005), *Musa* diversity loss is anticipated in Burundi. For example banana bunchy top virus (BBTV) has devastated several banana farms in low-lying regions of Burundi, such as the Rusizi valley in the North West. On the other hand, civil unrest disrupted the operations of the Burundi banana national research programme with resultant loss of archived information and a complete staff turnover. Efforts in the past to establish an *ex-situ* banana germplasm collection at Institut de Recherche Agronomique et Zootechnique were also interrupted. Population migrations could have also led to the disappearance or renaming of some cultivars. For example, Oketch and Polzer (2002) and Baghdadli et al. (2008) report that the conflict displaced farmers and destroyed infrastructure thus affecting agricultural production. In neighbouring Rwanda, similar population migrations before and during the 1994 genocide resulted in the disappearance or renaming of some cultivars (Nsabimana and van Staden, 2005). There is also a general consensus worldwide that genetic diversity that supports world production is being eroded (FAO, 1998).

The high demand for food and agricultural intensification has resulted in the selection and promotion of a few more productive/highly marketable cultivars worldwide, thus threatening genetic diversity. To curb this trend, the on-farm conservation of genetic resources has currently been given high attention (Brush, 1995; Bretting and Bellon et al., 1997; Duvick, 1997; Fowler and Hodgkin, 2005). The introduction of modern cultivars (improved hybrids) of staple crops appears to have also resulted in an overall decrease in genetic diversity, although within the released cultivars themselves the data are inconsistent and no overall narrowing of the genetic base can be discerned (FAO, 2010). An in-depth knowledge of current on-farm cultivar diversity and genetic erosion are therefore critical for formulation of strategies for the conservation of threatened cultivars with good/promising marketing or breeding qualities. More still, various socioeconomic, market and agro-ecological factors are known to play important roles in farmers' choices and management of crop genetic diversity at the farm, agro-ecosystem and community levels (Gauchan et al., 2005). Thus, an on-farm study of the *Musa* germplasm diversity in Burundi and the responsible socioeconomic and agro-ecological factors was needed to support *Musa* conservation and development in the country. This study therefore assessed the on-farm *Musa* germplasm diversity across different agro-ecologies of Burundi, farmers' selection criteria that create/maintain this diversity on-farm and *Musa* cultivar erosion in these agro-ecological niches.

MATERIALS AND METHODS

This study was conducted in 2007 through an on-farm *Musa* diagnostic study in the three Burundi provinces of Cibitoke (North-western Burundi), Kirundo (Northern) and Gitega (Central) (Figure 1). Burundi generally has a tropical highland climate, with a considerable daily temperature variation from one region to another, mainly due to the differences in altitude. The dry seasons are from May to August and from January to February, and the rest of the year is rainy. The average annual precipitation is about 850 mm (Wikipedia, 2013).

Banana (*Musa* spp.) in Burundi is mainly grown as cultivar mixtures on small subsistence scale with low inputs and with a mixture of intercrops including beans, sweet potatoes, cassava, sorghum and yam (Sebasigari, 1985; Baghdadli et al., 2008; AATF, 2009). For example, banana-yam, banana-beans, banana-beans-yam, banana-cassava-beans, banana-sweet potatoes-sorghum intercrops are commonly observed (Sebasigari, 1985).

The three study provinces were selected based on the high importance of the *Musa* crop for food and income in the farming system and the variability in the altitudes. It was postulated that the importance of banana and the variability in these provinces would offer a higher chance of capturing a representative *Musa* cultivar diversity for Burundi.

Cibitoke lies in the low altitude belt of the Rusizi valley [about 1000 m above sea level (masl)], which includes areas around the shores of Lake Tanganyika and the valley of the river Rusizi. It has a mean annual temperature of 23°C and receives between 750 and 1,000 mm of rainfall annually (Wikipedia, 2013). Plantains (*Musa* AAB) (though few) and 'Yangambi Km5' (*Musa* AAA) are grown in this area which is less suitable for east African highland (*Musa*

Figure 1. Map of Burundi showing the three provinces of Kirundo (mean altitude of 1,490 masl), Gitega (1,601 masl) and Cibitoke (1,130 masl) and the fields sampled for the *Musa* germplasm diagnostic within the districts in 2007.

AAA-EAH) bananas (Sebasigari, 1985; Blomme Guy, personal communication, 2012). Kirundo province lies in an intermediate altitude zone (1000 to 1500 m). Its annual rainfall varies between 1300 and 1600 mm and the mean monthly temperatures varies between 12 (Minimum) and 18°C (Maximum) (Wikipedia, 2013; World Weather Online, 2013). Gitega on the other hand lies in the medium altitude zone (1500 to 2000 m), which is the most important zone in terms of agriculture and livestock. This medium altitude zone is particularly suitable for growing Arabica coffee and high altitude bananas (Sebasigari, 1985). It receives between 1300 and 1600 mm of rainfall annually while the monthly temperature varies between 12 (Minimum) and 18°C (Maximum) (Wikipedia, 2013; World Weather Online, 2013). The median land size at the time of the study in Gitega and Kirundo was 0.4 ha and in the Rusizi plains 1.0 ha (Ouma et al., 2011). High access to markets and the presence of local farmers' organizations and NGOs interested in banana production and with the capacity to scale up project activities beyond the project action sites was also considered in the selection of the study sites. The study also ensured that gender and wealth status typology (poor, moderately rich and rich) was considered.

This on-farm diagnostic study built on participatory rural appraisals (PRA) and baseline surveys conducted in the same provinces in 2006 by the Consortium for Improving Agriculture-based Livelihoods in Central Africa (CIALCA) (CIALCA, 2008). These PRA and baseline surveys were executed in sites that cut across existing biophysical/socioeconomic gradients of banana production in Burundi. The PRA and baseline surveys solely relied on information derived through focus group discussions and household interviews, while this on-farm diagnostic study quantified farming systems through actual field measurements.

Across all sites, we studied 132 farms, each having at least 50 banana mats/ stools. Data were collected on on-farm *Musa* germplasm diversity, socio-economic use options/practices that create/ maintain cultivar diversity on-farm, and farmers' perception of culti var disappearance/genetic erosion. Data was captured using direct field measurements and an interview schedule that had both open ended and close ended questions. *Musa* cultivar names obtained during farmer interviews were subsequently verified by the national staff working on banana and checked against the National Banana Germplasm Collection database at the Institut de Recherche Agronomique et Zootechnique, Burundi.

We conducted discrete data analyses by sites and generated frequency distribution tables and bar charts using SPSS (Version 17) (IBM Corporation, 2008) and MS Excel software.

Musa diversity was determined by the number and relative abundance of *Musa* cultivars in the study communities or eco-system, often referred to as species diversity. Species diversity is a function of the number of species present (richness) and the evenness or equitability (relative abundance) of each (Hurlbert, 1971). Various indices and models have been developed to measure diversity within a community (Magurran, 1988). In general, three main categories of measures are used to assess species diversity: (1) species richness indices, which measure the number of species in a sampling unit, (2) species abundance models, which have been developed to describe the distribution of species abundances, and (3) indices that are based on the proportional abundances of species, such as the Shannon and Simpson indices (Magurran, 1988). The most commonly used indices include the log series, species richness, Shannon index, and the Simpson index (Magurran, 1988). These diversity indices determine which populations to target for conservation to maximize diversity or to model services provided by diversity (Gauchan et al., 2005). In this study, diversity was measured using the species richness (Equation 1) and the Simpson index, D, (expressed as Gini Simpson/ Simpson index of diversity 1–D) that measures relative abundance (*Equation 2*). GenStat 11th Edition (VSN International Ltd, 2008) was used to compute the species richness and the Simpson 1-D indices.

Species (cultivar) richness summed the number of different distinct banana cultivars regardless of their frequencies across the study sites/communities. This index is completely insensitive to cultivar frequencies (Jost, 2006). It gives as much weight to those cultivars that are represented by very few plants as to those cultivars which are represented by many plants (Jost, 2006; Dyke, 2008; Colwell, 2009). The cultivar richness (diversity of order zero) was computed as

$$D=\sum_{i=1}^{s}Pi^{0} \qquad 1$$

Where, cultivar i comprises the proportion Pi of the total individuals in a community of S individuals.

Hurlbert (1971) points out that, although species diversity and species richness are often positively correlated; situations do exist in which increases in species diversity are accompanied by decreeses in species richness.

The Gini-Simpson index (1-D) that is evenness is a measure of how similar species are in their abundances (Magurrun, 1988). Thus, an assemblage in which most species are equally abundant is one that has high evenness. The opposite of evenness is dominance, which is the extent to which one or a few species dominate the community (Magurrun, 1988). The Gini-Simpson index (1-D) takes account of the number of individuals of each cultivar as well as the number of cultivars within a community (Gauchan et al., 2005; Jost, 2006). It is conventional to equate high diversity with high evenness (equivalent to low dominance) (Magurrun, 1988).

$$D = \sum_{i} \{n_i \times (n_i - 1)\} / (N \times (N - 1)) \qquad 2$$

Where, n_i is the number of individuals of cultivar i and N is total number of individuals of all cultivars.

To determine the most important cultivar selection criteria (socio-economic use options/practices) that created/maintained cultivar diversity on-farm, farmers were presented with nine different cultivar selection criteria to select and rank in order of importance. Farmers' responses were then compiled and the means analysed using a multivariate principal components analysis using GenStat 11th Edition (VSN International Ltd, 2008) to determine the most important selection criteria across farms.

RESULTS

Agro-ecological niches of the study area

The selected provinces varied in mean altitudes. The mean altitude for farms sampled was 1,130, 1,490 and 1,601 masl in Cibitoke, Kirundo and Gitega, respectively. Altitudes greatly influence the type of banana cultivar to grow and the prevalence of pests and diseases with high prevalence in low altitude areas. For example, banana bunchy top disease, black sigatoka, banana weevils and burrowing nematodes are more prevalent at low than the high altitudes (above 1500 masl). The high altitudes are also characterised by the presence of moderate to steep slopes that are prone to erosion (van Asten et al., 2004), thus affecting the quality of soils.

Musa cultivar diversity in Burundi

Thirty-three (33) cultivars were recorded in total across the three provinces of Burundi (Table 1). The highest number of cultivars/cultivar richness was observed in Gitega province (30), followed by Kirundo (27) and Cibitoke (12). Eleven (11) cultivars were found widely grown across all the three provinces, while 16 and eight cultivars were grown across two and in only one province, respectively.

Cultivar evenness/relative abundance also varied across the provinces, with a markedly higher Simpson 1-D index recorded in Kirundo (0.79) and Gitega (0.76) compared with Cibitoke (0.65) (Figure 2). This suggests that compared with Kirundo and Gitega, Cibitoke is dominated by fewer cultivars. For example, 80% of the banana landscape in Cibitoke is occupied by two cultivars ('Yangambi-Km5' and 'Igitsiri') compared with 68% in Gitega and 63% in Kirundo. Similarly, across the entire country, 62% of the banana landscape is dominated by only two cultivars (6%), 'Igitsiri' (AAA-EA beer, 31%) and 'Igisahira gisanzwe' (AAA–EA cooking, 31%). Other cultivars of significant importance across Burundi include 'Igipaca' (AAA-EA beer, 9.4%) and 'Yangambi-Km5' (AAA beer, 5.8%). The remaining 29 cultivars in Burundi occupy only 23% of the banana landscape and those with low cultural significy-cance are vulnerable to genetic erosion, thus necessita-ting their conservation *ex-situ*.

Cultivar distribution by use

Beer banana types (57%) dominate the banana land-scape in Burundi followed by cooking types (38%) (Figure 3). Similar trends were observed across all three pro-vinces. The highest frequency of beer-producing types was observed in Cibitoke (88%), followed by Gitega (55%) and the least in Kirundo (52%). Cooking types were more dominant in Kirundo (43%), followed by Gitega (40%) and the least in Cibitoke (10%). The results reflect the fact that Cibitoke has specialized in beer

Table 1. *Musa* cultivars recorded in three provinces of Burundi (Kirundo, Gitega and Cibitoke), their respective genome groups, main use and mat coverage (%) in 2007.

Cultivar name	Genome group	Main use(s)	% overall mat count (N=132)	*Musa* mat coverage by province		
				Kirundo (N=60)	Gitega (N=56)	Cibitoke (N=16)
'FHIA'	?	D/B	0.03	0.03	0.04	-
'Gros Michel'	AAA	D	1.46	1.89	1.53	0.50
'Igifysi'	AAA	B	0.01	-	0.03	-
'Igihonyi'	AAA	B	0.65	0.98	0.49	-
'Igipaca'	AAA	B	9.41	8.45	10.68	5.94
'Igisahira gisanzwe'	AAA	C	30.72	34.85	32.54	6.11
'Igisahira namwezi'	AAA	C	0.01	0.01	-	-
'Igisahira Uganda'	AAA	C	0.01	-	0.03	-
'Igisubi[a]'	ABB	B	1.43	0.81	1.99	2.04
'Igisukari[b]'	AAA	D/ B	0.23	0.19	0.34	-
'Igitsiri[c]'	AAA	B	31.24	28.52	35.16	27.79
'Ikimaraya[d]'	AAA	D/B	0.52	0.53	0.54	0.44
'Ikingurube[e]'	AAA	D	0.52	0.46	0.75	-
'Ikingurube maraya[f]'	AAA	D	0.02	-	0.04	0.06
'Ikiyove'	AAA	B	2.12	2.14	2.83	-
'Imporogoma[g]'	AAA	C	0.05	0.10	-	-
'Inabukumu[x]'	AAA	B	0.25	0.38	0.16	-
'Nakitembe'	AAA	C	0.33	0.69	0.03	-
'Incakara'	AAA	C	1.88	3.06	1.17	-
'Indyabarangira'	AAA	C	0.01	0.01	0.01	-
'Intobe[h]'	AAA	C	0.23	0.48	0.06	-
'Isha'	AAA	B	3.31	5.75	1.67	-
'Kamaramasenge'	AAB	D	1.49	1.51	1.71	0.39
'Kamaramasenge Rwanda[i]'	AAB	D	0.20	0.19	0.25	-
'Mbwazirume'	AAA	C	2.61	2.45	3.11	-
'Mujuba[j]'	AAA	C	2.19	1.64	2.39	3.96
'Muzuzu[k]'	AAB	P	0.01	-	-	0.11
'Nzovu'	AAA	B	0.01	-	0.03	-
'Pisang awak[l]'	ABB	B	3.04	4.68	2.03	0.22
'Poyo'	AAA	D	0.01	0.01	0.01	-
'Rugamba[y]'	?	D	0.02	-	0.04	-
'Sila'	AAA	C	0.14	0.11	0.21	-
'Yangambi- Km5'	AAA	B	5.81	0.08	0.14	52.45

A dash (-) indicates that the cultivar was not recorded in this province. In the main use column, B is beer; C is cooking; D is dessert and P is plantain; Cultivar synonyms: a, 'Kisubi', Ney Povan; b, Red Banana, 'Ikisukari', 'Ikinyarwanda gisanzwe'; c, 'Inkira', 'Inuntu'; d, Giant Cavendish; e, Dwarf Cavendish; f, Giant Cavendish; g, 'Mpologoma'; h, 'Igisahira Intobe', 'Igisahira inabukumu'; i– 'Prata'; j , 'Igisahira namujuba', 'Inamujuba'; k, 'Mzuzu', 'Imuzuzu', Imisusu; l, 'Kayinja'. x , beer variant of 'Intobe'; y, missing in IRAZ collection 'Igisahira' means cooking; 'Gisanzwe' means normal, habitual, common; 'Namwezi' , the colour of spathes and bud

production, resulting in a reduced diversity of cultivars. For example, 'Yangambi Km5' a robust cultivar that can survive under adverse conditions and with minimal management occupied 53% of the banana landscape. Plantains (0.1%) were only recorded in Cibitoke.

Cultivar selection criteria

The principal components analysis indicated that the first and second principal components of all the three use groups (cooking, dessert and beer) accounted for almost 100% of the variation (Figure 4). Flavour, taste and juice quality and market demand/prices contrasted with the other seven selection criteria in principle component (PC) 1 across all banana use groups. Across all the banana use groups, the plot of PC1 and PC2 ranked flavour, taste of pulp and juice quality as the most important selection criteria, while market demand/ prices ranked second. Other selection criteria grouped together as less important in Burundi.
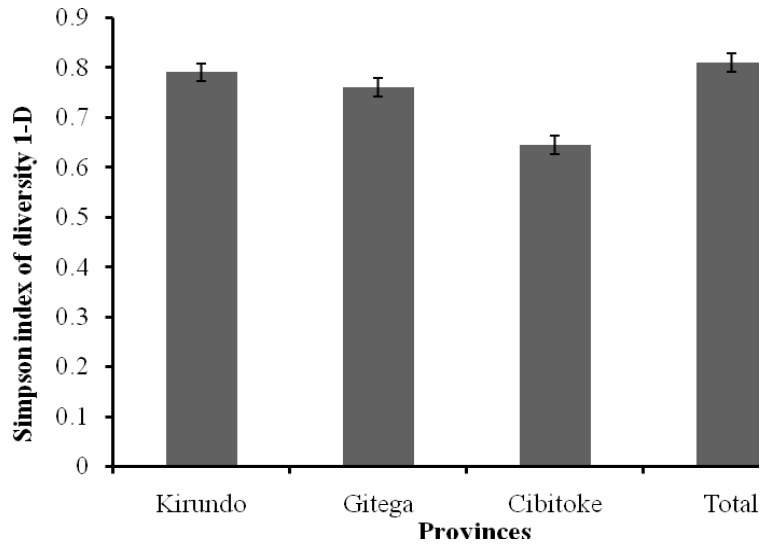
Figure 2. Simpson indices of diversity 1-D of *Musa* cultivars across three provinces of Burundi. Data was collected during a germplasm survey in 2007. Vertical bars are jackknife standard errors.
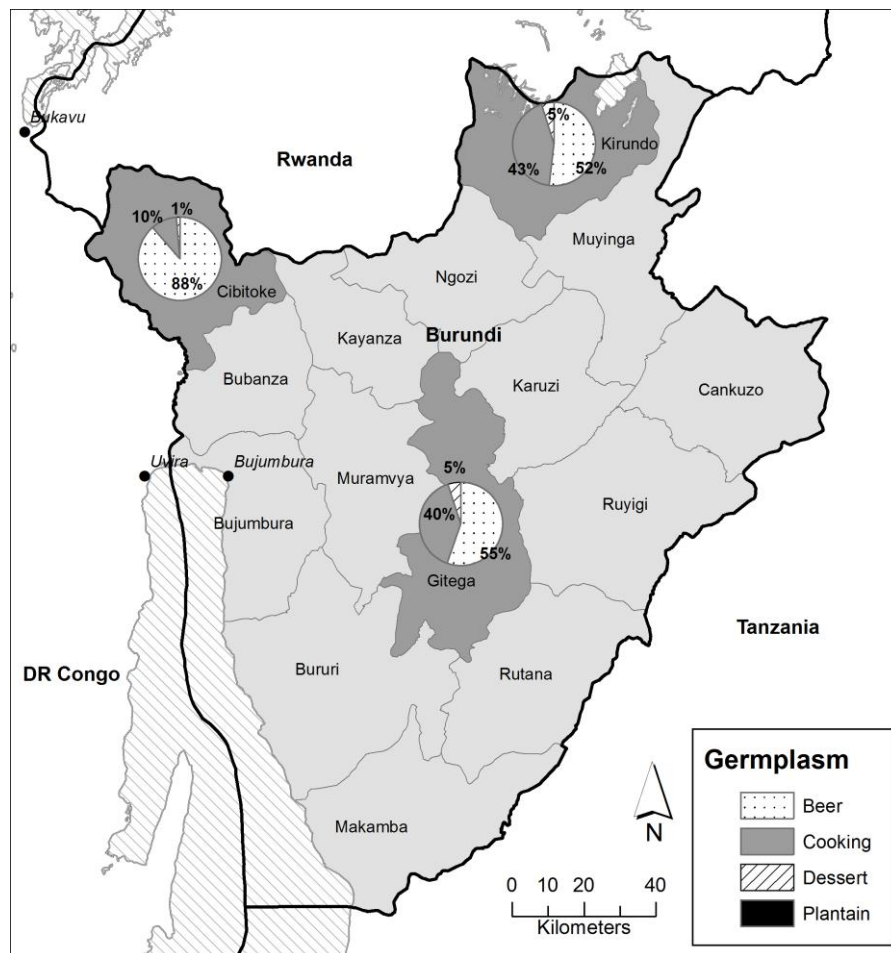

Figure 3. *Musa* cultivar distribution by use in three provinces: Kirundo (mean altitude of 1,490 masl), Gitega (1,601 masl) and Cibitoke (1,130 masl) in Burundi in 2007.
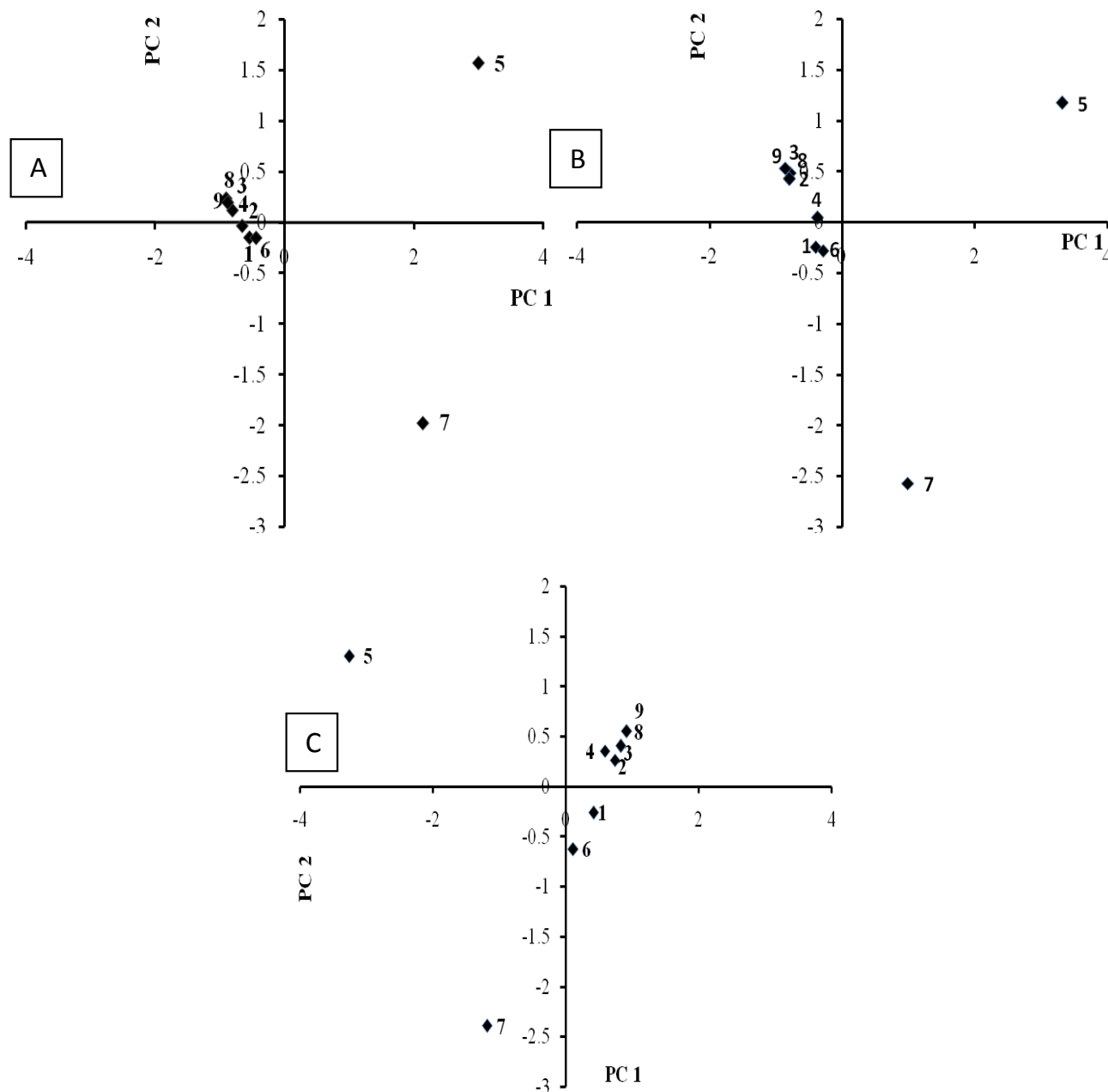
Figure 4. A plot of the first principal component (PC 1) scores against the second principal component (PC 2) scores for cooking (a), dessert (b) and beer (c) cultivar selection criteria in Burundi. Selection criteria 1 to 9 denote: 1, availability of planting materials; 2 , big bunch size; 3, resistance/ tolerance to soil infertility; 4, drought resistance; 5, good flavour, taste and juice quality; 6, Sustainable/ long mat production life span; 7, high market demand and/prices; 8, short production cycle; and 9, resistance to pests and diseases. The selection criterion 5 is ranked as very important, 7 important and the rest as less important.

Cultivar disappearance

Thirty percent of the respondents in Burundi reported that some cultivars had been lost (disappeared) and they as such do not grow them on their farms. The highest culti-var loss was reported in Cibitoke (69% of respondents in Cibitoke), while only 29 and 19% of respondents reported cultivar loss in Kirundo and Gitega, respectively. Cultivar

loss declined with increase in altitude. The most affected cultivars in order of importance included 'Kamaramasenge' (AAB dessert), 'Igisubi' (ABB beer) and 'Pisang awak' (ABB beer). Other cultivars reported that lost included 'Igisahira gisanzwe' (AAA-EA cooking), 'Igihonyi' (AAA-EA beer), 'Gros Michel' (AAA dessert), 'Mujuba' (AAA-EA cooking), 'Ikingurube' (AAA dessert), 'Muzuzu' (AAB Plantain), 'Inyakaburura' (AAA-EA cooking), 'Ingoromoka'

(AAA-EA cooking), 'Inyabukumu' (AAA-EA cooking), and 'Poyo' (AAA dessert). Diseases (reported by 89% of farmers) were the major perceived cause of cultivar disappearance in Burundi. Other perceived causes of cultivar erosion included drought (6%), lack of compost (4%) and weeds (1%). About 77% of the farmers respond to cultivar loss by replanting with resistant cultivars or materials from neighbours, while 3% of farmers uproot, cut and dry affected plants in the sun.

DISCUSSION

Musa cultivar diversity (richness and evenness) varied across Burundian agro-ecologies. *Musa* diversity was influenced by the interaction between altitude, farmer selection practices and diseases. High diversity was observed in the mid and high altitude provinces of Kirundo (mean altitude of 1,490 m) and Gitega (1,601 masl), respectively, while the least occurred in the low altitude area of Cibitoke (1130 masl). Low altitudes with high temperatures and rainfall support growth of plantains, while mid to high altitudes support growth of east African highland bananas (Sebasigari, 1985). Altitude also influenced the prevalence of diseases, especially BBTV. A high BBTV incidence (30%) and that of its aphid vector *P. Nigronervosa* has been reported in Cibitoke (Niyongere, 2012). Across the three provinces four cultivars out of 33 occupied 77%, while the rest occupied the remaining 23% of the area. This could reflect a shift to "commercially" oriented banana production with preferred banana cultivars for the market selected by farmers. For example, good flavour, taste of pulp and juice quality; and high market demand/ price for a cultivar were the most important selection criteria used by farmers. Jarvis et al., (2008) argue that high dominance, with much of the richness held at low frequency, signals a management strategy for diversity maintained as an insurance to meet future environmental changes, social and economic needs. Dyke (2008), in contrast, argues that when a community is dominated by only one or a few species, it may be that the rarer species are at risk of disappearing from the site. Moreover, such a distribution pattern may indicate that the habitat lacks a sufficient diversity of structure, patchiness, or resources to allow many species to exist together (Dyke, 2008). The less common cultivars, with low cultural significance, could thus be vulnerable to genetic erosion and their conservation is recommended.

Beer banana types dominated the banana landscape in Burundi. The predominance of banana beer cultivars can be attributed to the fact that beer is not perishable and can be stored for long periods and transported over long distances. In addition, beer bananas are reported to be more tolerant to adverse growing conditions and low levels of management (Gaidashova et al., 2005). The higher dominance of beer types (88%) in Cibitoke reflects the specialization in beer production in this province. 'Yangambi Km5' (*Musa* AAA, beer) a robust cultivar that

can survive under adverse conditions and with minimal management occupied 53% of the banana landscape in this province. This province has a low altitude (mean altitude 1130 masl) with low mean annual rainfall (750-1000 mm). This agro-climate is not fully favourable to highland banana cultivation. In addition, the low altitudes are often characterised by high disease pressure that could have decimated the production of other cultivars. For example, high incidences and severities of banana bunchy top disease, black sigatoka, banana weevils and burrowing nematodes occur at low altitudes. Plantains (0.1%) were only recorded in Cibitoke. This can be attributed to the fact that plantains thrive best under high temperature and humid conditions (Sebasigari, 1985).

Higher incidences of *Musa* genetic erosion were reported in the low altitude area of Cibitoke (69% of farms) decreasing markedly with the altitude. Diseases (89% of farms) were reported as the major cause of *Musa* genetic erosion. BBTD indiscriminately affects all *Musa* cultivars in the low altitudes of Cibitoke, while AAB dessert types 'Kamaramasenge' and ABB beer type 'Pisang awak' are affected by Fusarium wilt. BBTV infected plants are stunted and produce small deformed bunches with no market value, while in advanced stages; plants produce no fruit (Su et al., 2003). High incidence of BBTV (30%) and its aphid vector *P. Nigronervosa* have been reported in Cibitoke (Niyongere, 2012). On the other hand, Fusarium wilt caused by *Fusarium oxysporum* f.sp *cubense* infects the roots of banana plants, colonizing the vascular system of the rhizome and pseudostem, causing wilting mostly 5-6 months after planting (Stover, 1962). Infected plants produce no bunches or bunches with very small fruits. In addition, the fruits ripen irregularly and the flesh is pithy and acidic.

This fungus survives in soil for up to 30 years as chlamydospores in infested plant material or in the roots of alternative hosts (Ploetz, 2000) making its control difficult. Thus banana production is often unprofitable in areas severely affected by these diseases and as a result farmers gradually abandon the crop for other alternative non-traditional crops. For example, farmers have opted for sweet potatoes and cassava as coping strategies after devastation of banana fields by Xanthomonas wilt in Uganda (Kalyebara et al., 2006; Karamura et al., 2006), though the disease was not yet reported in Burundi at the time of this study.

Good flavour, taste of pulp and juice quality; and high market demand/ price for a cultivar were the most important criteria used by farmers to select cultivars to grow or maintain on their farms. This implies that cultivars not able to offer these attributes, even if good in other attributes such as disease resistance and tolerance of drought, are likely to be ignored in this region and risk being eroded from the *Musa* gene pool. Cultivars not liked by farmers in one region therefore need to be identified and conserved in gene banks. More still, *Musa* crop breeding and or adaption programmes should focus

on attributes preferred by farmers.

Conclusion

Musa cultivar diversity (richness and evenness) varied across Burundian agro-ecologies and is declining or under threat. Only four cultivars occupied 77% of the banana landscape suggesting a possible shift to production of commercially-preferred banana cultivars of high market potential, with another 29 cultivars occupying the remaining 23% of the area. The less common cultivars, with low cultural significance, are vulnerable to genetic erosion and conservation is recommended. *Musa* diversity in Burundi was affected by the interaction of altitude, farmer selection practices and diseases. Diversity increased with altitude from low-lying Cibitoke to the high altitude of Gitega. Diseases were more devastating in the low altitude areas of Cibitoke. The BBTD epidemic has affected all *Musa* cultivars at the lower altitudes. Fusarium wilt also affects AAB dessert types and the ABB beer types in this region. The most affected cultivars included 'Kamaramasenge' (AAB), 'Igisubi' (ABB) and 'Pisang awak' (ABB). The most important farmer selection criteria across Burundi were flavour, pulp taste and juice quality and market demand/prices.

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