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Banana Cultivar Names, Synonyms and their Usage in Eastern Africa

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Bioversity Kampala

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Foreword

The work being presented in the following text was first presented by curators of the banana collections in East Africa in 2004, at the then Hotel Equatoria, Kampla, Uganda during the banana synonyms workshop. During the workshop, curators described the germplasm in their collection as well as provide and recognise the probable synonyms in the different presentations that were given. Banana germplasm curators have long been plagued by an inability to unambiguously identify and describe cultivars in their own collections, and indeed it took sometime to verify what they considered synonyms or homonyms based on their presentations. Other curators also imposed constraints that included their own differences in terms of training and management experiences.All these together with their differences in priorities and attitudes contributed to the delay in verifying and correcting some of this information, hence the delay in reporting the results which came from the synonyms workshop. The text therefore provides a summarized review of each banana group found in the region, their local nomenclature and synonyms identified in each group.

In the same workshop, several germplasm scientists provided an overview of the tools that can be used to identify and describe materials in the germplasm collections, providing the advantages and disadvantages of each of these tools. The text finally summarises the recommendations which were made by curators proposing mechanisms of updating the synonyms tables. It also provides recommendations on the existing infraspecific classification schemes of the banana crop.

Introduction

The East African region covering countries of Kenya, Uganda, Tanzania, Rwanda, Burundi and the eastern part of the Democratic Republic of Congo constitute the East African plateau where bananas (*Musa* spp.) reach their greatest importance as a staple as well as a cash crop. The plateau is home to a diversity of cultivated *Musa* genotypes generally known as the East African highland bananas, chief of which are the Lujugira- Mutika subgroup (AAA-EA). Traditionally the Lujugira Mutika is referred to as Matooke that dominate the Great Lakes region of Kenya, Uganda, Tanzania, Rwanda, Burundi and the eastern part of the Democratic Republic of Congo (DR Congo). The Illalyi (AAA) dominates the Kilimanjaro, Usambara and Pare mountain foothills, the Mshare-Nshonowa (AA) have colonized the Meru-Kilimanjaro axis; and the Muraru–Mucuuru (AA) are grown on the foothills of Mount Kenya (Karamura, 2006). In addition, over the years, a number of genotypes have been introduced and locally adopted in the farming systems of the region. These include Pisang Awak (ABB); Bluggoe and Monthan (all of ABB group), Ney Poovan (AB), Silk, Mysore, Pome Kamaramasenge and Plantains (AAB), Red/Green-Red, Gros Michel, Cavendish (all AAAs) and different FHIA hybrids. Furthermore, there are other lesser known non described diploids that are said to occur in the coastal zone of East Africa, from Mozambique in the south to Ethiopia in the north, as well as those in Pemba and Zanzibar (De Langhe, 2009). The Democratic Republic of Congo also includes an important diversity area for plantains. Overall it is estimated that there are more than 100 indigenous cultivars in eastern Africa and the eastern Democratic Republic of Congo and just less than 50 exotic cultivars that have been introduced in the past 100 years.

The banana diversity index is highest around the Great Lakes areas where annual *Musa* consumption rates reach 400-600 kg/per person, the highest in the world and where banana crop acreage reaches 20-30% of the area under cultivation. More than 20 million people in the region are estimated to depend on the crop for their livelihoods, in terms of income and food security. It is widely believed that without bananas, several countries of the region would be net importers of food (Karamura, 2000).

Bananas have evolved in this region to suit the local environment so that different groups have adapted to various agro-ecologies of the region. Over years of interaction between farmers, bananas and the diverse environments, thousands of landrace cultivars with distinct traits have emerged and the East African bananas whose names are now too numerous to catalogue have

continued to make work difficult in terms of identification, classification and nomenclature. There are two different groups of users of bananas in the region. The first group consists of people who grow, sell and use the crop and who have generated a naming system which suits their needs without reference to any code of nomenclature. The most acceptable type of classification in the region is the user-driven one where bananas are divided into the cooking, beer, dessert and roasting cultivars and then descriptive names are used to differentiate cultivars within the user groups. This allows farmers to categorize diversity using relevant user or morphological criteria, a process which creates a pattern of naming and grouping cultivars. Although locally named cultivars can be recognised by the use of their end products, farmers usually do not agree over the identification of a particular cultivar. The most widely used scientific classification of bananas is that of Simmonds where bananas have been scientifically classified into genome groups, a group which includes cultivars at the same ploidy level and share the same genomic formula and these are very well established. Genome groups have further been subdivided into subgroups on the basis of shared attributes of cultivars by banana scientists although much still needs to be done on the standardization of names. The scientists who are the second group of users of the crop require the right naming system of banana cultivars and they need a standardized system of identification and nomenclature.

Field collections have been established in the region of East Africa, at Kawanda and Mbarara in Uganda; at Maruku, Tengeru, Morogoro and Zanzibar in Tanzania; at Gitega in Burundi, at Rubona in Rwanda, at Kisii and Thika in Kenya and at Mulungu in Eastern DR Congo. The initial purposes of maintaining these collections were to work out duplicates, identification and classification of theses materials. Now that bananas in East Africa are threatened by numerous pests and diseases, national collections have been assembled to locate useful resistances to improve the different accessions in these collections. Maintaining living collections of bananas is costly, evaluating them is even more so. Curators of bananas and other germplasm collections need standardized names, while breeders, crop protection scientists and extension workers need in some way to select a distinct set of accessions from the national germplasm collection for initial evaluation and then a means of locating other accessions likely to have similar properties to any accessions found to be desirable. To conduct their work and communicate their results, this group of users need standardized names of distinct cultivars. There has been an increased interest in the use and exportation of bananas and their products from the East African region, but the usage and

correct nomenclature of cultivars under consideration have always been a problem. Further to these establishments, the collections are not fully representative of the complete diversity in the region. An evaluation of these collections for their representativeness of the genetic diversity in the region as well as usefulness to breeders is very much necessary. Curators of national collections in eastern Africa met therefore to review the existing banana groups and sub-groups in their region with the aim of proposing a sort of standardized catalogue to explain the synonyms within each banana group, propose mechanisms of updating it as well as making recommendations on the existing infraspecific classification schemes of the banana crop. In the following texts, a number of presentations by curators in East Africa were made to 1) describe the different subgroups in the region and their probable synonyms and 2) to propose the way forward in dealing with the nomenclature and classification problems of these bananas.

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1

The usage of banana names in East Africa, with reference to Lujugira-Mutika sub-group (*Musa* AAA)

Mgenzi Byabachwezi, Mkulila Shaban and Karamura Deborah

Introduction

Although the East African plateau is considered a secondary centre of diversity of bananas particularly the Lujugira-Mutika subgroup, the region is not a major player in the global market, and the export potential of these bananas has not been exploited as an alternative source of income for the small scale farmers. The region however, is rich in its banana diversity with over 100 cultivars savoured and exploited. Farmers in East Africa describe these cultivars by names related to one or more traits at various development stages of the plant life cycle, like agronomic performance, uses of plant parts or aesthetics. Factors farmers use to describe and name cultivars are interrelated and provide a set of agro-morphological criteria which define a landrace (Karamura, 2008). However, as time goes on, the names become too many for ease of reference and some have been proved to be synonyms and homonyms. Not much is known about the structure of farmers' nomenclature of these landraces and its relevance to the botanical descriptors and classification. The endless range of banana cultivar names is considered to be one of the major problems of the banana crop in the region and there are several reasons for the existence of so many names. The changing nature of the crop in different environment and the phenomena of mutations do contribute to the problem of naming of banana cultivars but there is also lack of standardized tools and methods of proper identification of cultivars (De Langhe, 1988). The purpose of this paper is to describe the local naming system of bananas in East Africa with regard to the East African Highland bananas and assess its strength and weakness with reference to the standard naming of bananas.

Fig.1: The local classification of bananas in East Africa with reference to Uganda

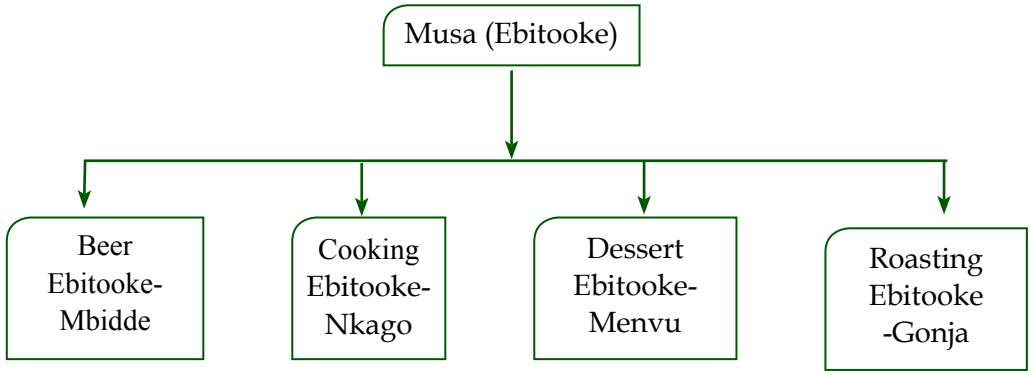


Figure 1 illustrates how farmers broadly group bananas in Uganda on the basis of use. This is the same classification throughout the region but with different names (table 1a). While this classification is good, it breaks down when it comes to the fact that any banana of any scientific grouping can be used in any of the given ways depending on any cultural or ethnic group. Then the classification becomes useless here.

Table 1a. Banana grouping based on use in Tanzania

Basis of naming		Name	Site where name used
Use	Brewing cultivars	Embire/Enkundi	Kagera
		Omutsiri	Kigoma
		Ng'ombe	Arusha and Kilimanjaro
		Ndizi	Throughout Tanzania
	Cooking	Ekitoke kisamunyu, Matoke, Ndizi za kupika	Throughout Tanzania
	Roasting	Enkonjwa, Gonja, Ndizi ya kuchoma	Throughout Tanzania
	Dessert	Kiise, Ntotomya, Ndizi Mbivu	Throughout Tanzania

Although majority of bananas are used for eating and drinking, some cultivars falling within these broad use groups are used for curing diseases or delivery problems e.g. Lwekilo in Kagera region of Tanzania, while others like Enchoncho (where chochoza means traditional rituals) are used to remove bad omen from

newly married couples. In Uganda, the Lujugira-Mutika cooking bananas are described further as 'ebitooke ebiganda' meaning that they are native to Uganda, in particular the central region and Ndizi Uganda or Enganda in Tanzania meaning from Uganda.

Among the main factors that have maintained these landraces for quite sometime, is their diversification in use particularly as food and production of local brew. Beer cultivars produce either strong alcoholic drink, medium and weak drinks, hence at times they are named according to the strength of the drink they produce. The brew is affordable by the community, and it is on high demand for social functions and boosts the producers (farmers and brewers) income. Local beer plays a major role in social gatherings such as funerals, festivities and people contribute either local beer or banana bunches to their hosts instead of money in cash which is a limited resource in most communities in the region. It is a requirement to contribute local beer processed from bananas before bride price is accepted in most parts of the region where banana is an important crop.

Local naming of bananas in East Africa

Within the groupings based on use of end products, bananas are named according to their characteristics in form of appearance, production rates of suckers, maturity period, and the crop's response to various environmental conditions. Tables, 1b-1d provides some useful examples of names in Kihaya, Tanzania and their meaning.

Table 1b: Names based on pseudostem and suckering characteristics

No.	Names in Kihaya Tanzania	characteristics
1	Enjuta (Tz), Namwezi (Ug.)	The pseudostem has no blotches. Name related to clear stem with no blotches.
2	Enzirabushera	Stem is pale green with dark brown spots like the paste from the finger millet (bushera)
3	Kazilaiko(Tz), Naluyonga (Ug.)	The pseudostem is continuously black to the petioles
4	Nfufula	Has blotches like that of the puff-adder snake
5	Entuku (Tz), Entukula (Ug.)	Both the pseudostem and petioles are purplish red
6	Mushaijaranda	The pseudostems develop into a semi-prostrate position
7	Ntalibwambuzi	The young suckers produce true leaves at the height not reachable by the goat.
8	Entobe	Short and strong psuedostem and fingers
9	Engumba (Ug.)	Rarely produces suckers i.e. barren stomach

Table 1c: Names based on bunch and fruit characteristics

No.	Names in Kihaya Tanzania	Characteristics
1	Enyitabunyonyi	When it matures, becomes compact and if there is a bird's nest, the birds are pressed and killed
2	Nyabwehogora	When mature the hands can easily be removed off the peduncle or fall off themselves
3	Enzinga	Have one spiralling hand
4	Basige'kyobaizile	Produces enormous bunch with many hands and visitors forget their objectives and instead discuss the bunch
5	Enjubo	Have big fruits compared to hippo size.
6	Makungwe	Fingers are extremely short and sometimes never develop to useful fingers
7	Mfichachana	Fingers are long and curve inwardly towards the rachis.
8	Empindwi	Fingers look like the weaving tool
9	Nyamahwa	Fingers have spines
10	Kigere (foot)	When young the fingers are flat like the foot of a human being
11	Ensenene (grasshopper)	Fingers have green and mild brownish spots like Nsenene (grasshopper)
12	Enshaka (bush)	When young fingers are haphazardly arranged (some facing up and some down). In addition, both neuter flowers and bracts are persistent on the axis making them look like a bush

Table 1d: Names based on various characteristics

	Names in Kihaya Tanzania	Characteristics/appearance
1	Enkila (tail)	After the female fingers the axis becomes very long comparable to the tail
2	Entaragaza	Persistent neutral flowers
3	Kinunu	Prominent Floral remains on fruits
4	Ekitoke-enkungu	Banana without a male bud
5	Kyanabalya	Is a very fast maturing cultivar possibly the fastest so that when the flower comes out a farmer is assured of food in few days.
6	Mukail'alikisa (beer)	'The giving old woman' as it gives a lot of juice
7	Nshagya (beer)	Gives juice sweeter than others
8	Nyamaizi (beer)	Produces more juice but it is not sweet
9	Enshazi (beer)	Produces strong astringent sap.
10	Ntagola	Even in bad conditions it gives a bunch
11	Nyakasha	Does better where there is cow dung

Value of local names in the standard naming system

Local names provide the first information on cultivars and their classification. They form a basis for the development of a more dependable classification system in the situation where there is no reference to the cultivars in the region. There is need however, to develop a checklist with banana key local names and this should contribute to the standard naming system so that their usefulness is appreciated.

Majority of banana landraces have originated through mutations and selection and those who live by cultivating these plants are usually acutely aware of the differences affecting either the appearance or the quality of the variants they grow. These variants keep getting names and as the number of variants increase, it becomes difficult to identify them unless they are grouped in some way to indicate shared or different attributes. In the following chapters, different banana subgroups are discussed to see how useful their naming and classifications have been on the basis of their shared attributes in the East African communities.

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2

The current classification and naming of the East African highland bananas (*Musa* AAA) based on morphological characteristics

Karamura Deborah, Karamura Eldad, Nsabimana Antoine, Ngezahayo Ferdinand, Bigirimana Spes-Caritas, Mgenzi Byabachwezi, Mkulila Shaban, Munyuli Theodore, Musakamba Matembanyi, and Tendo Ssali

Introduction

The East African Highland bananas (*Musa* AAA) locally known as the Matooke are largely found in subsistence systems/small holdings of the East African region, thriving on altitudes between 900-2,000 meters above sea level; hence they are now more often called the East African Highland bananas (EAHB). The crop occupies a large part of the East African Plateau which covers Uganda, Rwanda, Burundi, Eastern Democratic Republic of Congo, North-Western Tanzania and Western Kenya, with temperature ranges of 10-30^{o}C. Although 78% of the banana crop in the region is overwhelmingly dominated by the EAHB which has an estimated diversity of 80 -150 cultivars, there are other banana groups described in the text grown in mixtures with the EAHB on the basis of farmer cultivar proportions (Karamura et.al 2004, Nantale et. al, 2008). The average range of cultivars per farm in the region could then be between 30-40 different cultivars.

In Tanzania, apart from Kagera region, the highland bananas are grown in Kigoma, Mbeya, Kilimanjaro, Arusha, Tanga, Tarime district in Mara region and some parts of Morogoro region (Mgenzi Byabachwezi, Mkulila Shaban, 2004). In Uganda, the crop is grown in all parts which do not experience a pronounced dry season; these include areas within about 80 kilometres of the shore of lake Victoria, the south western highlands, the slopes of Mt. Elgon in the East and the well watered areas of the western part of the country. In Kenya, although there are few EAHB clones, bananas are widely grown in the western part, in areas surrounding Lake Victoria, on slopes of Mt. Kenya and along the coast. The highland bananas are also dominant features in the landscapes of Rwanda, Burundi and eastern part of the democratic republic of Congo. More than 20%

of the area of Rwanda is occupied by bananas of which of these, more than 65% represent the East African Highland bananas (Nsabimana et. al. 2008). In the democratic Republic of Congo, the East African highland bananas are mainly produced in highlands of North-Kivu and South Kivu (900-2,900m of altitude; 1-2° S, 25° -28°E) and the annual production ranges from 2,600 tonnes to 80,000 metric tons per year (Munyuli and Musakamba Matembanyi, 2004).

Compared to other bananas, the EAHBs represent the biggest proportion of bananas in the region and are important for food security and income generation in the peasant farming communities. They play an important ecological role, especially in the maintenance of soil fertility and fecundity, and in the control of soil erosion in the highlands and mountainous areas of East Africa. Apart from being used as a major food crop, the EAHBs are a major source of local wine and beer which are both sources of income and drink for the local communities in the region.

Basic morphological descriptors of Lujugira- Mutika subgroup

Lujugira –Mutika is the name given to the East African Highland bananas as a subgroup and was proposed by Shepherd (1957). It covers the beer and cooking clones of East Africa. The Lujugira-Mutika is also often referred to as *Musa* AAA-EA after De Langhe et. al., (2001). In East Africa these bananas are considered to be extremely tasty and perhaps rare bananas of the world. They seem to have evolved in East Africa through mutations and farmers' selection, and they may have other names, which apply to the subgroup as a whole or to individual cultivars. The highland bananas are robust with more than three meters high with exceptions which could be mutants. The pseudostem colour is green (Chart A, Descriptors for bananas, 1996) with a glossy appearance and with a pink purple underlying sheath. The green appearance of the pseudostem is mottled with black or brown or a mixture of both and the degree of mottling can depend on the cultivar together with the environment. The beer bananas are often very extensively blotched, particularly during rainy seasons and in the presence of fertile volcanic soils. The pseudostem of cooking bananas can also be as dark as the beer bananas if it is growing under very fertile conditions. The pseudostem produces a milky sap, although a few members have colorless sap. Wax is present on the upper leaf sheaths, on leaves of young plants as well as on male buds, but the degree of waxiness on these parts depends on the cultivar and the development stage of the plant. The rate of production of suckers is cultivar dependant and

the developing suckers can grow as close to the parent or abit far apart from the parent. Majority of suckers grow vertically in most cultivars while in one or two individual clones, they grow while slanting (e.g *Musa* AAA 'Mukazi-alanda'.). The petiole is straight with a canal which is open with margins spreading. The leaf habit is intermediate between erect and drooping and the colour of the leaf upper surface is the rich dark green while that on the underside is silvery green. One clone is known to have a purplish leaf upper surface (*Musa* AAA 'Bitambi') and another one with variegated leaf upper surface (*Musa* AAA' Nasuuna'). The lamina of most highland bananas tends to split along the veins much more than in other banana groups. The highland bananas have no blotches on leaves of water suckers. Male buds are purplish blue brown with a few members with red purple, green-purple or yellow male bud and showing an imbrication of bracts in the Nakitembe clone set only. The colour of the bract internal face is orange red but fades to yellow towards the bract base. The bracts of most highland bananas open out and roll back before falling but the rolling is much more reduced in the Nakitembe clone set. The overall colour of the male flowers is whitish with no pink coloration in the compound tepal and the free tepal is translucent, with no thickening of the central midline. The anthers are pink with a cream filament although one or two of the five anthers remain aborted (black in colour). The central rachis remains bare except in members of the Nakitembe clone set, (where it is covered with persistent neuter flowers and bracts) and shows various orientations which includes that of falling vertically, or being at an angle, or with a curve or being sub horizontal. Similarly the bunch shows similar orientations depending on a clone set, and with a roughly hairy bunch stalk. The bunches range from small to big sized bunches with individual fruits arranged out at right angles or 45 angle or parallel to the central axis. The fruits can be loosely packed, or compact or very compact. The fruits can be straight, angular and or curved like a canoe, typically lengthily pointed or "pinched" at apex. Rarely, do we find fruits with inflated tips. Young fruits have a distinctively dark rich green colour, although a few members have a bright glossy green colour (*Musa* AAA 'Namafura') while others are variegated (Musa AAA'Nasuuna' and 'Kabende'). The fruits are not always uniformly aligned in the bunch especially the top hand. The fruit pulps are white to cream, and orange brown at ripeness with 3 loculi *not* easily detachable. The highland bananas are primarily for cooking, not really for picking and eating immediately out of hand. Their textures are firm to very firm or even highly astringent (beer), and when very ripe, the pulp is still firm and bitterish in the beer clone.

Fig. 2a: Diagnostic characteristics of the Lujugira-Mutika subgroup



Pseudostem and upper sheaths extensively pigmented black or brown



Undersheath deep pink purple and very glossy



Leaves dirty dull green and deeply split along the veins of the lamina



A purplish blue brown male bud



Pink Anthers



Dark dirty green non waxy fruits

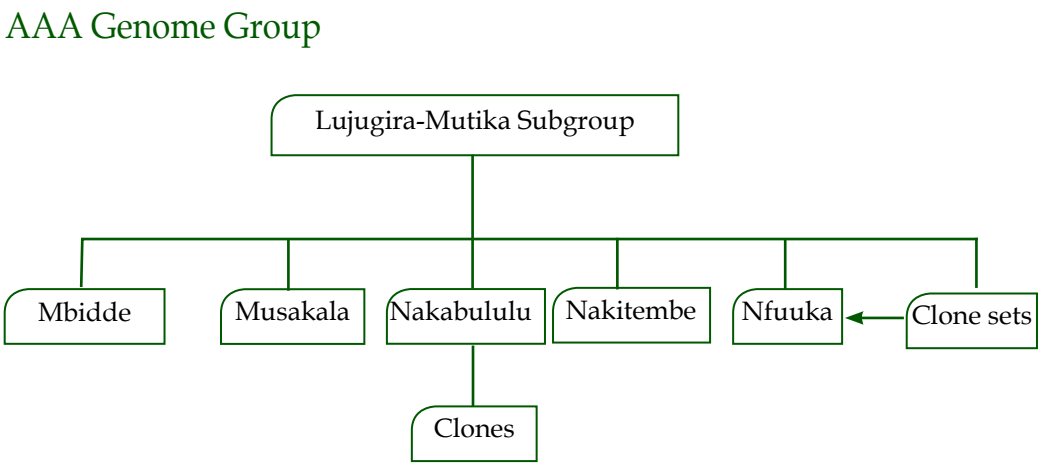
In summary the highland bananas are characterized by the glossy pseudostems intensively blotched with black/brown or bronze; pink-purple undersheaths; robust dirty dull green leaves with deeply split lamina along the veins; dull purplish blue brown male bud; male flowers with pink anthers; dark dirty green non waxy unripe fruits.

When fully ripe, the EAHBs can be eaten raw like dessert bananas but they are more often cooked green by the communities in the region where it evolved. In Uganda, they are locally known as Matooke a word which is generally used to mean bananas but matooke in Uganda also means the thick yellow matooke prepared from the cooked and mashed fingers. Beer bananas are known locally as Mbidde (Luganda dialect) or Mbiire (Lunyankore /Lukiga /Kihaya). In all banana growing areas in the region, the most acceptable type of classification is the user-driven one, and users are often more diverse than the users of the standard taxonomic treatment. Scientifically, the East African Highland bananas are triploids (genomic formula AAA), containing the A genome of *Musa acuminata,* (Shepherd 1957; Stover and Simmonds, 1987) the diploid wild species from where all cultivated bananas are believed to have evolved. They consist of bananas used for cooking and those used for beer where the two together form what Shepherd (1957) called the Lujugira-Mutika subgroup of the AAA genome group. Genome

groups are well-established among banana scientists, though the genomic formula is often used as a prefix to a more descriptive name (without any indication of rank) which may distinguish a subgroup (Lujugira-Mutika) within a genome group (AAA). No terms have been consistently used to designate the clusters or sub clusters of clones within the subgroup. The East African Highland bananas have however, been sorted out into five morphological groups called clone sets (Fig 2b). Local names were adapted for each clone set since they were describing the most observable characters of each clone set. Just like in all other classification system, there are few accessions which do not fit well in any single clone set but fall into 2 or 3 of the clone sets because they share characters of those clone sets. These were placed in a clone set where they showed the highest discrimination function (Karamura, 1999).

In each of the East African countries, there are some clones which have been used by communities for quite a long time both as food as well as in cultural functions. Such clones have formed subpopulations through mutations and selection to probably form what Lebot et. al., (1994) called base clones. In Tanzania, *Musa* AAA 'Enshansha' has formed its own subpopulation whereas in Rwanda and Uganda it is *Musa* AAA, 'Nakitembe'. Further more, in Rwanda there are many beer and cooking clones which have been generated in the region through both selection and mutations but also due to altitude and soils causing the diversity of EAHB in Rwanda to be slightly different from other countries (Nsabimana and Gaidashova, chapter 3 of this publication).

Fig.2b: The classification of the East African Highland bananas (Karamura, 1999)



Mbidde (Beer) clone set

The word Mbidde describes the astringency and bitter nature of the fruits of the members of this clone set. There are not many other morphological characters which have defined this clone set although majority are completely black along the length of their pseudostems. However, the clones in this clone set share characters with members of other clone sets in such a way that clones of other clonesets (Musakala,Nakabululu, Nakitembe and Nfuuka) have corresponding Mbidde clones. For example there is Ntundu cooking in the Nfuuka clone set and Ntundu with astringency fruits hence a beer clone, the two differing only in astringency fruits and darker pseudostems of the beer clone set. This means that the Mbidde clone set defined morphologically does not coincide perfectly well with the Mbidde clone set defined by bitter fruits (i.e. by use). The data of the classification study based on the overall morphological similarity (Karamura, 1999), however, suggested that most Mbidde clones resemble one another in number of morphological characteristics in addition to being bitter fruits, and so formed a coherent group that has been evolving separately from the cooking bananas for some considerable time (Pickersgill and Karamura, 1999). Molecular studies have further confirmed that the four clone sets seem to be valid but not the beer clone set (Tugume, 2002; Buwa. 2009). Table 2a displays all the known EAHB beer clones with their synonyms in East Africa.

Table 2a. Major clones in the Mbidde (Beer) clone set (Karamura and Karamura 1994; Tushemereirwe et. al. 2001)

Uganda	Burundi	DR. Congo	Kenya	Rwanda	Tanzania
Endemera, Endembezi				Indemera	
Engote				Ingote	
Engumba	Ingumba	Ingumba		Ingumba	Engumba
Enkara	Makara			Inkara, Insiri	
Ensansa		Enyanza			
Ensika, Insika		Ishikazi		Inshika	Ensika
Ensowe, Katalibwambuzi					Entalibwambuzi
Entukura, Enjumba, Engambani, Umburasika, Emburasika	Ingamatayiri			Injumbura	Entukura, Entuku
Entanga, Enshenyuka					
Entundu, Nunda	Igitsiri,			Intuntu, Igishumbu, Inyumbu	Entundu
Kabula, Namadhi, Nametsi	Inyamaizi	Enyamaizi	Nyametse	Inyamaizi	Enyamaizi
Kyamalindi				Intembe	Entai
Luwuuna, Ekihuna	Igihuna	Chihuna		Igihuna	Enshaka-Mbiire
Lwezinga, Enzinga	Inzinga			Inzinga	Enzinga
Musajja-alanda Musajja-alanda			Maffukha	Mushaija-naranda	Endandalanda, Rwembuga
Nakanyala				Indenge	

Uganda	Burundi	DR. Congo	Kenya	Rwanda	Tanzania
Nalukira, Enyarukira, Inkurura	Inkira, Gashulie?			Rwabuganga	Enkila,
Nalusi,					
Nalwesanya					
Namunyere	Gashulie; Gashulio			Inshakabuhake,	Inshakabuhake,
Shombo-obureku, Ingoromora			Ngoromora	Ingoromoka	Chundabureku,, Kyundobureku
				Impyisi	
				Rugigana	
				Muzibwe, Inyamakure	
				Inkati	
				Isha	
				Inyabukumwe	
				Nyamabere	
				Intokatoke	

Musakala clone set

The word Musakala means lax and refers to the laxity of bunches of this clone set. Members of this clone set have pendulous bunches and male rachises, long fruits above 20 cm with bottle necked fruits, recurved towards the rachis. In *Musa* AAA 'Muvubo' and , 'Namunwe', fruits are not recurved but more or less at right angle to rachis. Bunches are lax, usually with no persistent floral remains on the fruit tips and rachis, male bud not imbricate but with acute apex. Seems to be the most newly evolving clone set due to commercial selection.

Table 2b:) Major clones in the Musakala clone set (Karamura and Karamura,1994, Tushemereirwe et.al., 2001)

Uganda	Burundi	DR. Congo	Kenya	Rwanda	Tanzania
Kisansa, Namayovu, Musisi, Rwamigongo, Rwabakongo				Njagi	
Lumenyamagali					
Lwewunzika, Lusingosingo					
Mukazialanda, Musenze-alanda, Walulanda, Mulandani			Maffukha	Mushaijanaranda	Endandalanda, Rwembuga
Mpologoma , Nakibizzi, Mutule, Murure, Mudwale, Muturit, Wansimirayo, Batule, Gafabugisu, Mugisuagenda		Intudde			
Musakala, Enshakara, Nshakara	Enchakala			Barabeshya Indundi	Enkande, Enchakala
Muvubo,Mujuba, Weetala, Mulwaddetayasama	Mijuba		Enjobo	Mijuba, Mujuba	Enjubo, Namujubu
Namunwe, Namuunga, Namamunga					Enaganage
Njoya	Inyoya			Inyoya	Enyoya

Nakabululu clone set

Nakabululu indicates short, compact bunches and fruits, but also means that all fruits ripen simultaneously. Clones in this set have sub- horizontal to oblique bunches and male rachis, bunches are very compact with short fruits below 15cm, and almost perpendicular to rachis. The rachis usually have no persistent floral remains on the fruits and rachis, although a few of the clones have semi-persistent floral remains on the rachis (*Musa* AAA, 'Butobe', 'Kibuzi', 'Sala-lugazi' 'Nakyetengu', 'Entente'). Male bud not imbricate but with an obtuse or rounded apex. Kibuzi , Sala-lugazi Nakyetengu (Uganda), Entaama and Enjunjuzi (Tanzania) are considered to be intermediate clones between clone sets. They have a higher discrimant function for Nakabululu than other 3 clone sets and hence are placed in Nakabululu. They have some characteristics of Nakabululu, Nakitembe and Nfuuka clone sets.

Table 2c: Major clones of the Nakabululu clone set in the region (Karamura and Karamura,1994, Tushemereirwe et.al., 2001)

Uganda	Burundi	DR. Congo	Kenya	Rwanda	Tanzania
Butobe (Kafunze, Wekhanga)	Intobe			Intobe	Entobe
Kattabunyonyi, Muttabunyonyi, Muteeba-Nyonyi	Chibulangombe				Enyitabunyonyi
Kibuzi, Khabusi	Nyakibuzi			Kayuku	Enshansha
Mukubakkonde, Bifusi, Bikumpu, Makofu, Ndiza-bawulu				Inyabutembe, Ingenge	Entente
Nakabululu, Embururu, Tindemwa, Butende, Invururu	Nyambururu			Icyerwa-Ntoya	Entente, Embururu
Nakabululu omumyufu Nakasabira, Mukite,					

Uganda	Burundi	DR. Congo	Kenya	Rwanda	Tanzania
Nakabululu omuddugavu Kazirikwe, Nakayonga	Kazirikwe				Kazilaiko
Nakyetengu Ekitetengwa, Nasherembwe, Kitika		Kitika kisamunyu		Nyekitengwa, Impyisi	
Nakyetengu omuwanvu					
Salalugazi					
Nasikhohe, Sikhohe					
					Nyamawa
					Enshwera
	Intama			Intama	Entaama
					Enjunjuzi
				Kintu	

Nakitembe clone set

The word Nakitembe means 'like ekitembe'. Ekitembe is the local name for enset plant, a plant considered to be the wild banana in the East African region. Members of the clone set resemble enset in that the bracts and floral parts of the male flowers persist on the rachis (semi-persistent in Musa AAA 'Engagara'). The name Nakitembe also relates to the Luganda word okutembuka which implies hurrying, i.e. maturing in a short time. The clones have oblique to pendulous bunches and male rachis, compact bunches, fruits of medium size (15-20cm), not strongly re-curved towards the rachis, with persistent floral remains on fruit tips and rachis, and male bud imbricate with intermediate shaped apex (between acute and obtuse).

Uganda	Burundi	DR.Congo	Kenya	Rwanda	Tanzania
Nakitembe-Nakawere; Malira-Lufuta; Malira-Lunyirira,					
Nakitembe-omumyufu					
Nakitembe-omusoga					
Namaliga, Maliga, Kiriga Musibampina; Buziddume, Rwakashita,				Kirayenda	Empuni
Nandigobe; Enjagata; Ntinti; Engagara; Gonzowa; Toro Kongowet;Endyabawali Narwanda; Nasaala-umudwale, Enyaruti, Enyamuti, Enyanti, Kawali, Entabawali	Ingagara	Entabawali Kiwari Mbawali, Muhana-binyoko	Munjuu, Kikuyu 1	Ingagara	Engagara
Nasaala; Garuchura					Endiibwa?
				Intutsi	

Table 2 d: Major clones in the Nakitembe clone set (Karamura and Karamura,1994, Tushemereirwe et.al., 2001)

Uganda	Burundi	DR.Congo	Kenya	Rwanda	Tanzania
Bikowekowe, Lisandalo 2, Nakitembe omunyoro					
Kyewogola	Nyamwihogora			Nyabwihogora	Nyabwehogora, Enkokomero
Luwuuna, Ekihuuna; Oruhuuna	Nyalutembe?	Chihuna, Cintege-C'iru		Igihuni, Rugigana	Enshaka
Mbwazirume; Embwairuma; Tsirume, Mbwaziruma, Mpito, Mbwerima	Mbwaziruma	Mbwazirume		Rwabugenyi; Mbwaziruma Bagabobarandya	Mbwairuma, Mwanaalifa, Ndizi Uganda
Nabuyobyo,					
Nakibule, Waikova, Nekolemale					
Nakitembe; Entaragaza; Malira; Enshembashemba Lisindalo 1 Malira-Omunene, Potyo Nangesyet, Nyakitembe; Nakitembu, Nakitembwe,	Igihonyi	Luntubugu	-	Nyakitembe; Entaragaza	Entaragaza
Nakitembe-Nakamali; Namulondo, Malira-Nakangu, Malira-Omutono, Nakamali					

Nfuuka clone set

The word Nfuuka means 'I am changing'. This is a dynamic clone set with some morphologically unstable clones. It is the most heterogeneous of the clone sets and also contains the highest number of clones. A number of clones in this clone set overlap in characters with other clone sets. It is assumed that this could be the original clone set (Karamura, 1999). Clones in this set have oblique to pendulous bunches and male rachis, bunches compact with fruits of medium size (15-20cm), and are not strongly recurved towards the rachis. The persistent floral remains are absent on fruit tips and rachis, and the male bud not imbricate with an intermediate shaped apex (between acute and obtuse) (although one or two clones have semi-persistent floral remains e.g *Musa* AAA 'Mukadde-alikisa').

Table 2e. Major clones in the Nfuuka clone set (Karamura and Karamura,1994, Tushemereirwe et.al., 2001)

Uganda	Burundi	DR. Congo	Kenya	Rwanda	Tanzania
Atwalira, Nassaba, Katereke					
Bitambi				Naironi	Lwekilo, Lwekilo-Ntuku
Bukumo, Busatsi, Enkonera, Kisugunu	Enyaghenghe	Nyaghenghe		Inyabupfunsi, Rusatsi, Inyamafuri, Ishoki	Makungwe, Kinunu, Enkungwe, Enkukumwa
Entundu, Nunda Inyumbu		Ntuntu, Ndundu		Intuntu	Entundu
Enyamanshari, Kanyamanshari Kanyamanswa	Nyamabere				Empindwi
Kabende, Walubende					Enzimora
Katwalo, Entazinduka, Enjoga, Enjogabakazi, Kanyesese, Nakasese, Kabucuragye, Namunyere			Mugithi		Endishi, Ndizingombe, Nuru, Enjoga, Empigi, Enganda
Kibalawo, Enzirabahima Muziranyama	Inzirabahima			Inzirabahima	Enzirabahima

Uganda	Burundi	DR. Congo	Kenya	Rwanda	Tanzania
Kibiddebidde	Mbirabire				Embirabire
Lusumba, Namamuka				Bakurura?	
Lwezinga, Enzinga, Enyarwezinga, Nalwezinga				Inzinga	Enzinga
Mukadde-alikisa					Mukaile-alikisa
Mukazimugumba, Nakibira	Ingumba Inyamunyu			Ingumba Inyamunyu	
Nabusa, Enyeru, Enkobe, Likhago, Enjeriandet				Inconnu, Inyamunyo	Enchoncho, Endeishya
Nakabinyi					Enkila?
Nakakongo, Nyakagongo, Enyakagongo					
Nakawere, Kasenene, Karinga, Endyabagore					
Nakhaki, Nakhagi, Kasese					
Nakijumbi,Nambokho Namande,					
Nakinyika, Kafuba, Simba-lukono, Kufuba, Kifuba, Enjuuma, Enyakinika				Intama?	Entaama?
Namafura					
Nambi, Namakhumbu, Sitakange, Makhumbu-musooba					
Namwezi					Enjuta?
Nante, Nabirye, Nsabaana					Nante
Nasuuna, Lwefusa, Namunye					Enshule

Uganda	Burundi	DR. Congo	Kenya	Rwanda	Tanzania
Ndyabalangira, Kagayi, Enzirabushera	Inzirabu shera			Mutsimawuburo, Inyonza, Inzirabushera	Enzirabushera
Nfuuka, Ntika				Ingaju, Icwera-Nini	
Lwaddungu					
Serunjogi Kulwoni, Kaasa.					Enjuta?
Siira	Insira			Insira	
				Intaliho	Entalio, Ensikira?
				Nyakababi	
				Rugondo	
				Bakurura	
				Insiri	
				Inyambo	
				Inyabukumwe	
				Insana	
				Inyamico	
				Bakungu	
Tereza					
Tuulatwogere					

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3

The local nomenclature of the East African highland bananas (*Musa* AAA) in Rwanda and its challenges

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Importance of bananas in Rwanda

The East African Highland bananas constitute a major food and cash crop in Rwanda and the annual production has increased since 1996 from 2,105, 397 tons to 2, 658, 232 tons in 2006, respectively (NISR, 2008). Rwanda is the second largest banana producer in Africa after Uganda with 145.4 kg per capita consumption per year (FAO 2000) and the crop is cultivated on 183, 148 ha. (NISR, 2008). Rwanda is a country with high population density (>400 people/km^2) where land holdings are small and still bananas are intensively cultivated in homesteads that are small and easy to manage. Most of the banana production is subsistence oriented and banana is intercropped with beans, cocoyam or sweet potato. (Okech et.al., 2005). The banana crop occupies 22.5% of the cultivated area under food crops in Rwanda (NISR 2008) and its contribution to country's Gross Domestic Product (GDP) is 6.7% or 19% of total agriculture contribution (NISR 2008). The crop is of great social importance in the country and beer made from bananas is considered a sign of sociability. Banana beer has been an obligatory element of every ceremony or traditional meeting for centuries. It is an indicator of prosperity and well being (Lassoudière, 1989).

There is speculation as to when bananas were introduced in Rwanda. Jurion and Henry (1967) and Sirven Sirven et.al., (1974) thought that banana cultivation in Rwanda was introduced during the 16th Century. However, Kagame (1972) reported that the introduction occurred earlier, during the time of governance of the 11th king of Rwanda named Mibambwe I (1411 – 1444). The different ways in which the crop is utilized indicate that the crop has been with the people of Rwanda for a long time. Banana cultivation in Rwanda occurs between 800 m to 2,000m above sea level and the country is subdivided into three major banana production zones: Kivu lake border, of western province Kigali, Huye axis of Southern Province and

Eastern Province where the East African highland bananas occupy 75-96%, the 10% and 67-90% of total banana area, respectively. Bananas are relatively expensive and they dominate the peri-urban areas, while brewing bananas gain big rural and urban market for banana beer where they are considered major cash crops. The use of banana in Rwanda is not limited to brewing and direct consumption as such, although these typically dominate in terms of consumption. Numerous processed non-food items ranging from toys for children to decoration of houses are made from various parts of banana plants.

Banana diversity in Rwanda

Banana cultivars in Rwanda are genetically diverse with all *Musa* groups (AA, AB, AAA, AAB, and ABB) almost represented although groups of AA, some AAA, AAB and ABB are considered to be of recent introduction in Rwanda (Lassoudière 1989). Based on the various subgroups of bananas mentioned in the introduction, Lujugira – Mutika sub-group still dominates in Rwanda (Nsabimana et al. 2008) but a number of different subpopulations seem to be evolving gradually and these seem to be different from those in Uganda and Tanzania (see tables 2b-2e). Research on bananas in Rwanda was initiated in 1953 with the establishment of the banana germplasm collection at ISAR, Rubona Research Station (Anonymous 1966). This collection contained only 11 accessions of highland bananas (EAHB) by then. Further research has focused on the introduction and evaluation of dessert (AAA) and beer banana clones (ABB). Collecting missions in the late 1980 resulted in the establishment of a new banana collection (ISAR 1992) which included local (AAA-EA) and exotic banana and plantain clones. This collection was rehabilitated in 1999 and enriched with new accessions in recent years (Nsabimana and Van Staden 2004). Currently, the National banana germplasm collection has more than 103 accessions which include 72 East African highland cultivars (AAA-EA). Majority of AAA-EA cultivars, belong to the cooking banana types (50 cultivars) and 22 cultivars belong to the brewing type (Table 3). The dominant nature of cooking banana clones may be due to wider utilization and diversification of its use due to farmers' selection.

Rwanda like Burundi, Tanzania and Uganda, has many banana cultivars existing with various names so that synonyms and homonyms are causing problems of identity of the clones. In Rwanda, local cultivars of highland bananas exist under different names depending on the geographic locality. In spite of the use of a single language in Rwanda it is often difficult to recognize whether the same cultivar exists under different names in various agro-climatic regions, or different cultivars exist

in different regions under the same names. The distinction among different clones is difficult as morphological characteristics change with environment. Inyamunyo seems to be the commercial name for all cooking bananas, while the name Inkakama is used for beer bananas. Inkakama means bitter in Kinyarwanda language. Farmers know only the clones that are in their areas and usually work out differences between cooking and beer bananas using the astringent and bitter tasting pulp of a beer banana. Some clones can easily be identified by their morphological traits such as stoloniferous pseudostem of Mushaija-Naranda, a spiraloid hand of the bunch of Inzinga, and the brown-green-red colour of leaves and green bunches of Naironi as indicated in the previous chapter. There are few synonyms in the national banana germplasm collection (Table 3) and some homonyms such as Mbwaziruma (Inzirabahima); Ingenge (Inyabutembe) and Injagi (Nyabwihogora). A catalogue of major highland banana clones in Rwanda follows this chapter with some synonyms. There are not many distinct morphological traits differentiating highland banana cultivars of Rwanda, and this makes the identification difficult. For instance, some clones fit only partially in the key proposed by Karamura (1999) for the clone sets because of intergrading morphological traits. However, it is always easier to distinguish between cooking and beer banana by tasting the pulp for its bitterness rather than to find differences among clones within clone sets. Molecular characterisation may be a useful tool to help in reducing duplication and simplifying the classification criteria for banana germplasm.

Threats and challenges to diversity of the East African highland bananas and their conservation efforts

Banana germplasm in Rwanda like everywhere else is experiencing threats due to declining soil fertility, low management standards, increasing market pressure and demand for few and high yielding cultivars. Other major factors contributing to loss of cultivars are pests and diseases. Some varieties have disappeared on farm and they exist only in gemplasm collection, while other clones have become very rare. Banana germplasm is conserved with the efforts of National Agricultural Research Institute (ISAR) and it receives a meagre budget for its maintenance. It is conserved as a field collection in a single site only, although a second site has been proposed. This makes it fragile in case of any disease which comes in the collection field. The National Banana Research Program has limited staff allocated to germplasm characterisation work. If diversity of the East African banana germplasm is to be conserved and utilized, then the value of its classification and nomenclature must be well understood. As mentioned in the previous chapter, there are few clones

of the EAHB which remain intermediate to the major clone sets and they can only be placed with difficulty in any clone set or can only be assigned by discriminant analyses on the basis of morphology. The four clone sets of the cooking bananas have been found to consist of clones which share characters important to farmers and consumers (Pickersgill and Karamura, 1999) and these four clone sets have been supported by molecular studies (Tugume, 2002). However, there is no molecular method which has managed to identify markers related to astringency although it is a major and useful trait among farmers. In addition, while morphological data suggest that beer bananas resemble one another in many morphological characters and the clones can form a coherent group, the beer bananas defined morphologically, do not coincide perfectly well with the group defined by bitter fruits (i.e. by use). The clones of the East African Highland bananas can therefore be sorted into four morphological clones which coincide to a considerable extent with the groups recognized by banana growers and consumers.

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Table 3: Some accessions of highland banana in the Germplasm Collection, Rubona, Rwanda with synonyms and homonyms

Clone Set	Cultivar/Clone	Synonyms/ Homonyms
Nakitembe	Mbwaziruma	Bagabobarandya, Inzirabahima
	Nyakitembe	Nakitembe
	Igihuni, Kirayenda, Intutsi, Kibuzi, Ingagara, Kayuku	
Musakala	Injagi	Incakara
	Mushaija-Naranda, Barabeshya, Mujuba, Mbirabire	
Nakabululu	Nyakitengwa	Nakitengwa
	Ingenge	Inyabutembe
	Inyabupfunsi	Inyamafuri, Ishoki
	Icyerwa Ntoya, Intariho, Intobe, Intama, Inyabutembe,	
Nfuuka	Mutsimawuburo	Inzirabushera, Inyonza
	Inzirabahima	Bagabobarandya, Mbwaziruma
	Inyamunyo, Bakungu, Rugondo, Intuntu, Insiri, Insana, Bakurura, Icyerwa Nini, Ingaju, Inyamico, Inconnu	

Clone Set	Cultivar/Clone	Synonyms/ Homonyms
Beer	Intuntu	Inkara, Igishumbu
	Muzibwe	Inyamakure, Umuzibwe, Imizibwe, Umuzibo , Imizibo
	Inkati, Insiri, Ingoromoka, Igihuna, Inshakabuhake, Nyamabere, Intembe, Rugigana, Isha, Impyisi, Ishika, Ingumba, Igihuna, Indenge, Inyabukumwe, Indemera, Ingote, Inzinga	

** Key for clone set determination was used from Karamura (1999)*

4

The local nomenclature of other *Musa* AAAs in East Africa (*Musa* AAA 'Gros Michel', 'Red' and 'Green Red' cavendish)

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Gros Michel

Gros Michel commonly known as Bogoya in East Africa is widely distributed in the region, growing at a slightly higher altitude range of 1,400 meters above sea level. It is an important banana in East Africa and is widely sold in all city markets in east and central Africa. Gros Michel has several other names. In Tanzania, it is widely known as Kijoge or Enjoge but it is also known as Musa, Malaya and Ndizi. Ndizi in Tanzania means Jamaica sweet (Mgenzi, 2004). The clone has a very tall vigorous pseudostem above 4 meters high, with long heavy bunches of long slender and bottle necked fruits above 20cm. The fruits ripen to a very bright yellow colour. Several mutations have been reported in Tanzania where the clone is a multipurpose type; used for cooking, dessert and beer making (Mgenzi,2004). More descriptions about the inflorescence can be found in Sebasigari, 1986 and Karamura, 1999. Gandu is a probable mutant of Gros Michel with a medium height pseudostem, and fruits which are a bit short below 20cms. When the fruit is raw it produces a more astringent sap compared to the common Gros Michel and produces hard food on cooking. Gandu is mainly used for brewing beer. Ngumadu another probable mutant of Gros Michel has a medium height pseudostem, with fingers which are relatively slender. It is very soft on cooking, not good for confectionery and used for brewing as well. The rest of the synonyms of Bogoya are presented in table 4a below.

'Red' and Green 'Red'

The two clones are widely distributed in East Africa although they are not economically important. In Tanzania they are called Kinyamutuku (meaning Red Sweet), Igisukari in Rwanda and Burundi, while in Uganda they are called Bogoya omumyufu (red) or Ekizungu or at times Siira They are back yard clones

grown for local consumption. They are not commonly used but ripened fruits are used in making beer as well as being eaten as dessert. The whole plant of *Musa* AAA Red is red including the fruits but this plant produces mutants with green red fruits. The clones have vigrous high stems above 4 meters high, with small bunches of plump fruits less than 15 cms of obtuse tips. The clones are slightly susceptible to Fuasarium wilt and resistant to black sigatoka. The clones are not preferred for confectionary purposes, so they are not highly favourable. The synonyms are in table 4b. and 4c respectively.

Fig. 4a



Green red

Fig. 4b



Red

***Table 4a: Musa* (AAA) 'Gros Michel'**

Burundi	DRC	Kenya	Rwanda	Tanzania	Uganda	Zanzibar
Gros Michel	Gros Michel	Kampala, Egerton	Mafuta, Gros Michel, Mbogoya	Enjoge, Kijoge, Ekijoge, Jamaica sweet, Malaya, Ndizi, Musa.	Bogoya, Bogoya omweru, Bogoya owa bulijjo, Balingwa (Toro), Sweet Jamaica, Malaya, Musindije, Musindishe,Sindikha, Eriongot.	

Table 4b: Musa **(AAA) 'Green Red'**

Burundi	DRC	Kenya	Rwanda	Tanzania	Uganda	Zanzibar
Igisukari	Cisukari-cuduku, Cingurube c'eka, Cisukari green, Cisukari mweupe, Buganda mweupe.	Neuse (Kikuyu), Uganda Red Indio Uganda.	Gisukari Igihushwamuhoro, Ikiziramuhoro.	Nyeupe ya Kizungu (Amani), Bokoboko (Amani), Mgomba wa Uganda (Moshi), Ndizi Uganda (Moshi), Iruu lya Uganda (Kimachame), Kikanda (Moshi), Musoma (Morogoro), Ndizi-nyeupe, Mzungu Mweupe.	Bogoya Omumyufu, Kizungu white, Bofulo, Epiakol, Ekijungu.	Mzungu mweupe (Pemba), Buki (Pemba).

Table 4c: Musa **(AAA) 'Red'**

Burundi	DRC	Kenya	Rwanda	Tanzania	Uganda	Zanzibar
Igisukari	Cisukari-cuduku, Cingurube c'eka, Ekirisirya. Cisukari Rouge, Mugombozi, Sukumba, Bumpavu	Neuse (Kikuyu), Gitune (Kikuyu), Nyarsausetti, Uganda Red.	Gisukari, Igihushwamuhoro.	Nyekundu ya Kizungu (Amani), Bokoboko (Amani), Mgomba wa Uganda (Moshi), Ndizi Uganda (Moshi), Iruu lya Uganda, (Kimachame), Kikanda (Moshi), Ikiziramuhoro, Mzungu Mwekundu,	Bogoya-omumyufu, Kizungu Red, Kibiddebidde, Ndiziteru, Bofulo, Namonye, Ekijungu, Epiakol.	Mzungu mwekundu, Bungala (Pemba).

Cavendish bananas in East Africa

Njuguna Kori Joseph

Cavendish bananas are dessert bananas which are triploids of *Musa acuminata* . Cultivars in this sub group form the basis of the world export trade amounting to only about 12% of all *Musa* productions worldwide (Stover and Simmonds, 1987). Cavendish cultivars are numerous and their identification is complicated by the limited number of morphological characters available and the effects of genotype x environment interactions on morphology (Daniells, 1990). Mutations from dwarf to tall and vice versa are very common, in addition to a number of named cultivars

which are actually synonyms of the same clone. Isozyme characters (Jarret and Gawel, 1995) and oligonucleotide fingerprinting (Kaemmer et al. 1992) also fail to distinguish between members of these closely related clones of this subgroup. However, RAPD analysis has distinguished different clones and has also distinguished an induced mutant from its parent cultivar (Kaemmer et al., 1992). Cavendish bananas on the whole are more productive than other cultivars, they produce big bunches with more hands and longer fingers, that turn yellow and have desirable flavour when ripe. The cultivars have considerable resistance to Panama disease caused by *Fusarium oxysporium Schlecht. F. cubensis (E.F.Sm) Synder and Hansen* but are susceptible to Black sigatoka disease.

Table 4d: Nomenclature of cultivars in the Cavendish subgroup in East Africa

No.	Name	Other names
1.	Dwarf Cavendish	Kisukari, Kike, Gatumia, Katumia, Nyoro, Chinese dwarf, Shirembe, Nyoro, Njuru, Kinguruwe, Kiguruwe, Kitika sukari, Kikuhi cindege.
2.	Kiguruwe (could be the same as Dwarf Cavendish)	Malindi, Mudatsi, Kingzika, Kimalindi , Kaduli,
3.	Giant Cavendish	Nyoro Ndaihu, Nyoro Njeru, William, Kimalindi, Cindege ya munene
4.	Valery	Israeli
5..	Lacatan	Israeli
6.	Grand Nain	Israeli
7.	Williams	Israeli, Giant Cavendish
8.	Paz	Israeli, Mtwishe, Mtwike, Paji
9.	Robusta	Israeli, Mtwike
10.	Chinese Cavendish	Israeli

The main distinguishing feature of members of Cavendish subgroup is the pseudostem height which can vary from less than 1 meter to over 4 meters for different clones (Robinson et al., 1993)

Varietal Characteristics observed in Kenya

Fig. 4c: Dwarf Cavendish



Short (1.2-1.8 m tall) stumpy, black stem which leans over and needs support when bearing fruit. Medium yellow fruit with average length of 18 cm. Bunch weight: 25-30kg. Prone to cigar end rot. Suitable for hot areas.

Fig 4d: Giant Cavendish



Medium tall plant at least taller than Dwarf Cavendish (2.6-3m). Huge fingers of average length between 22-24cm. Fingers are shorter than those of Valery. Big bunches of about 30kg. Flowering to harvesting: 4.5-5.0 months.

Fig 4e: Valery



Stem taller and thinner than Giant Cavendish (3.0-4.0 m). Bunch strongly re-curved towards pseudostem, with average weight of 30kg. Fingers slender (24-26 cm), long and strongly re-curved towards the rachis. Flowering to harvest: 4.5-5.0 months. Sometimes considered the same as Robusta by some taxonomists.

Fig. 4f: Grand Nain



Pseudostem strong and of medium size. Huge bunch like Giant Cavendish (30 kg). Fingers are well spaced not compact. Finger length: 22-24 cm. Flowering to harvesting: 4.5 – 5 months.

Fig. 4g: Lacatan



Plant taller than Valery and Giant Cavendish (4.0-5.0 m). Pseudostem strong and darker than that of Valery or Giant Cavendish. Average bunch weight 35kg. Finger length: 28-30 cm. Considered to be the tallest Cavendish.

Fig. 4h: Chinese Cavendish



Taller than Dwarf Cavendish (2.6-3.0 m)
Stem is bigger than Dwarf Cavendish
Flowering to harvest: 4.5-5months. Bunch is bigger than Dwarf Cavendish (30 kgs). Finger length: 22-25 cm

Fig. 4i: Williams



Plant is medium sized (2.6-3.0 m)
Flowering to harvesting: 4.5-5.0 months
Bunch slightly smaller than Grand Nain
Fingers are dark green even when mature
Finger size: 22-24 cm. Average bunch weight: 30 kg

Fig. 4j: Paz



Looks like Grand Nain. Planting to flowering: 9-11 months. Flowering-harvesting: 4.5-5 months. Average weight: 30 kg. Finger length: 22-24 cm

Fig. 4k: Robusta



Medium stem (2-2.2 m). Weight: 25-30 kg
Finger length 22-24 cm

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5

Plantains (*Musa* AAB) in East Africa

Talengera David, Karamura Deborah, Pillay Michael

Importance of plantains

The plantains constitute a subgroup of bananas within the AAB genome group (Simmonds, 1966; Swennen and Vuylsteke, 1987; Swennen 1990; Swennen and Ortiz, 1997) and they are commonly referred to as roasting bananas in East Africa. The name plantain has often been applied to all cooked bananas, however, there are two types of cooked bananas. The first type is where fruits are cooked when still green and these are not true plantains, while the second type, is cooked when fruits are ripe. The latter are considered true plantains since they can only be consumed when cooked (Swennen and Vuylsteke, 1987) and are often unpalatable when raw (Karamura, et. al., 1999). It is these plantains which are being considered in the following pages.

Plantains are grown on a small scale in East Africa and account for only 11% of the banana production in the region (Frison and Sharrock, 1999). The proportion of plantain in the farmers' banana fields are estimated to be 10% in Burundi, Rwanda and the Democratic Republic of Congo (Sebasigari, 1989) and 2% in Uganda (Gold *et al*., 1999). Several factors account for the low acreage of plantain in the region. The crop is very susceptible to weevils, have a low leaf production rate (Karamura *et al*., 1999), a poor root system (Vuylsteke *et al*., 1993) and high mat (Swennen and Ortiz, 1997). All these attributes collectively shorten the life span of the mats. Other factors are cultural. In the banana growing parts of Uganda and Tanzania, plantains are generally given a second consideration where by one to three mats are planted at the periphery of every banana plantation. In some parts, for example, central Uganda, the crop is associated with a bad omen thus limiting its popularity to the growers. The low supply of plantain fruits has made the fruits a delicacy forcing the prices to be triple that of the widely grown East African highland (*Musa* AAA-EA) cooking banana cultivars. Plantain fruits have wider uses both in the raw and ripe stages. Before ripening, the starchy pulp can be sliced, sun dried and processed into flour that is said to be very digestible and used for weaning babies in the western Democratic Republic of Congo. Ripe

fruits can be steamed unpeeled or peeled and roasted, the latter being the most common commercial practice. Ripened pulp can also be sliced and deep-fried. Unlike the East African highland cooking bananas that loses value at ripening, plantains can still be roasted, steamed or used for juice production at the over ripe stage. The beer brewed from plantain juice and known as "Amarwa" in the central region of Uganda is a delicacy that was drunk only by kings. In reference to post harvest qualities, plantains have a thicker peel that provides an effective protection to the pulp. This minimizes post harvest losses during transportation. The high starch content also gives the fruits a longer shelf life. Due to these post harvest qualities and the diversified utilization, farmers have found plantain growing more profitable. Apart from the fruit, several plant parts are said to have medicinal value. The roots are roasted and chewed by expectant mothers to speed up baby delivery. A small piece of fibre is tied around the neck to treat a stiff neck. Powder scraped from raw roasted pulp is used for sealing umbilical cords of newly born babies.

General description

The plantains are characterized by wide open bunches and large angular fruits which are seldom eaten raw. The pseudostems have shiny green-yellow colour and therefore farmers' in central Uganda have always grouped the plantain among the green bananas of the AB and ABB genome group. Most of the plantain pseudostems have a pink-purplish tinge that intensifies to red in some cultivars giving rise to a total red pseudostem. In plants where the red colour is predominant, the petiole, lower mid rib and the cigar leaf dorsal surface have a red-purple shade. Plantain leaves are intermediate, between erect and drooping wide and of medium length dark green with pronounced veins in the leaf lamina. Leaf blade bases are asymmetric and rounded. Leaf sheaths and petiole margins have a pinkish-purple tinge. The petioles are winged, curve inside, have a purplish margin and clasp the pseudostem at their bases. Petiole bases are waxy with small dark brown blotches. All plantain suckers have large purple blotches on leaves. Plantain fruits are generally slender and ridged. The fruit apex shapes range from bottle- necked, lengthily pointed. Some exceptional cultivars have fat fingers with rounded apices to blunt shaped. Because this characteristic make them resemble upland cocoyam tubers, in Uganda they are referred to as 'Nakakongo' in Luganda, and also due to the same resemblance to a cooking cultivar "Kibuzi" of the Nakabululu clone set (Karamura, 1999), these cultivars are at times called "Gonja wa Kibuzi" meaning plantain of the Kibuzi family. Fruit

size is variable among the plantain types and cultivars. Even within a cultivar, the soil conditions determine the fruit size. Fruit peel is light but waxy green before ripening, thick and peels easily after ripening. Plantain fruits have long pedicels and are persistent on the peduncle up to ripening. In plantain types with male buds, the bracts are red-purple, imbricate and do not lift nor roll back. The lobes of the compound tepals are orange. Of all the bananas in the AAB genomic group, plantains are known to have the starchiest pulp. They, however, develop a slightly sweet taste at ripening. In East Africa, plantains are given one collective local name wherever they are grown (see table 5a). Different plantain cultivars are given specific names most of which are descriptive of the vegetative parts or the inflorescence or bunch. The language diversity in the region is reflected in the names hence creating synonyms (Table 5b). Like any banana, a complete plantain inflorescence is composed of fruits (fingers) arranged in clusters (hands) attached on a bunch stalk (rachis). Below the last hand the rachis continues to grow down wards carrying groups of rather small neutral (hermaphrodite) flowers. It then terminates into a male bud composed of very small male flowers. The inflorescence type at maturity is the most striking difference among the plantain cultivars (Purseglove 1972; Swennen and Vuylsteke, 1987; Tezenas du Montcel, 1987). Thus, based on the completeness of the inflorescence and the presence of neuter flowers and male bud, plantains are conveniently categorized into four general types. Within each of these types are found different cultivars that are referred to by local names most of which are still descriptive of the vegetative parts or inflorescence type.

Table 5a. General nomenclature of Plantains in the region

No.	Country/Dialect	Common name given to platains
1.	Burundi	Muzuzu
2.	Democratic Republic of Congo	
	• Western	Makemba
	• Eastern	Mzuzu or Misheba
3.	Kenya (Maragoli)	Ngongia
4.	Rwanda	Umushaba

No.	Country/Dialect	Common name given to platains
5.	Tanzania	
	Swahili	Gonja
	Kihaya	Nkonjwa
6.	Uganda	
	Central, west	Gonja, Gonje
	Eastern (Soga)	Wette
	Eastern (Teso)	Adeke

The four plantain types are:

1. **French type**. These have a complete inflorescence of many hands (6 to 12) consisting of many rather small fingers (arranged in two rows). The last hand is followed by a long rachis covered with persistent neuter flowers, withered bracts terminating into a large male bud.
2. **French horn type**. The inflorescence in this category is incomplete i.e. many hands (5 to 8) consisting of slightly large fingers arranged in two rows. The rachis is long and covered with many persistent neuter flowers, male flowers. The male bud reduces gradually and will have disappeared at the time of bunch maturity.
3. **False horn type**. The inflorescence is also incomplete i.e. fewer hands (3-6) with medium sized fingers (arranged in one row). The rachis is short, covered with few persistent neuter flowers. The male bud disappears a few nodes after the opening of the last hand. Fruit size is one and half that of the French plantain.
4. **True Horn type**. This category has the most incomplete inflorescence. The hands are very few (1-2) with very big fingers arranged in one row on the hand. The rachis is a short stub that terminates just below the last hand with no trace of male bud (truncated). The fruit apex is lengthily pointed with fresh remains of style base.

There is, however, a tendency of the followers (ratoon) to switch from one type of inflorescence to another, a phenomenon referred to as inflorescence reversion. And when the change is from a once complete inflorescence (French) to one without a male bud (False horn, True Horn) the term inflorescence degeneration

is used (Vuylsteke, et. al., 1990). From further systematic studies inflorescence groups have been further categorized according to plant stature like Giant, Medium and Small (De Langhe, 1964; Swennen and Vuylsteke, 1987; Tezenas du Montcel, 1987; Swennen and Ortiz, 1997). But plant size, just like the finger size and number of hands, is very much influenced by the environmental conditions under which the plants are growing. Thus its application might be of limited use under the farmers' field conditions. Table 6b provides a number of the most widely grown clones in East Africa.

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Table 5b: Plantain synonyms, inflorescence type and description

Inflorescence type	Example	Description (at maturity)
French	Gonja Nakatansese, Gonja-Omuganda, (Luganda-UG) Musheba (DRC), Ishulungu, Igjindi, Nyamasolu (Burundi), Kigonjagonja (Ug.)	Many hands (6 to 12) with small to medium 15-20 cm biseriate fingers, persistent big male bud, neuter and male flowers, and withered bracts on rachis. Fruit apex bottlenecked. Green-yellow pseudostem.
French	Majaga, Gonja mukono (Luganda-UG), Kipanje (Amani), Mzigu, Mpalu (Tz), Kalasa (Ug).	Many hands (5-6) with small biseriate fingers. (5-10cm). Rachis has fewer neuter and male flowers and bracts
French	Gonja omumyufu (Luganda-UG), Red Plantain (Eng), Gonja Nshakara, Mchinja damu (TZ), Tsambunu (Rwanda) Nyagashaba, Umushaba 2 (Rwanda)	Many hands (5 to 6) with long (above 20cm) biseriate fingers. Rachis has fewer neuters, male flowers and bracts. Fruit slightly longer than Nakatansese with a lengthily pointed apex. Reddish pseudostem, petioles and lower mid-rib.
French	Gonja Nakakongo, Gonja wa Kibuzi (Luganda-UG) Nkonjwa-Mafuni (TZ), Kichaange (Zanzibar),Vuhindi, Nguma (DRC), Kimanzobonzo, Kinamutobisho.	Many hands (5 to 8) with fat and long biseriate fingers. Rachis has many retained neuters, male flowers and bracts. Male bud persist but in some cases gradually disappears as the bunch matures. Fruit slightly bigger than Nakatansese with rounded apex. Green-yellow pseudostem.
False Horn	Gonja Kakira, or Manjaya (Luganda-UG). Chayaya (Burundi), (Rwanda). Libanga, Kajabo, Manjabo, Majabaga (DRC), Umushaba 1 (Rwanda).	Few hands (3-6) with medium uniserate fingers (one and half times the size of French). Few neuter flowers. Male bud degenerated. Fruit apex lengthily pointed. Green pseudostem.

Inflorescence type	Example	Description (at maturity)
True Horn	Gonja mamba (Luganda-UG). Igihobe (Burundi), Nkonjwa-Chayaya, Nkonjwa mafunu, Mkono wa tembo, Mkonga wa Tembo, Mkono mmoja, Ndizi ya kiume, (TZ), Mbo, Mbwe, Msusu (Kimachame-TZ), Ngego (Tz), Umuzuzu (Rwanda)	Very few hands (1-2) with very big uniseriate fingers (triples the size of French), Rachis is just a stub and male bud never forms (truncated rachis). Fruit apex lengthily pointed with flesh remains on style base. Green pseudostem. Mzuzu (DRC,TZ), Cibula nana, Kingalwa,

DRC: Democratic Rep of Congo, Eng: English, TZ: Tanzania, UG: Uganda.

Major clones of East Africa (Figure 5a-5f)



Fig. 5a. Nakatansese (Uganda)



Fig. 5b. Kigonjagonja



Fig. 5c. Kalasa



Fig. 5d. Gonja Mukono (Uganda)



Fig.5e. Kakira (Manjaya, Chayaya)



Fig 5f. Gonja Mamba

6

Apple (AAB) and Muraru (AA) bananas in East Africa

Onyango Margaret

Introduction

A number of clones of *Musa* AAB "Apple" and *Musa* AA "Muraru" dessert bananas exist in East Africa and have been described with various names. While some cultivars within these two groupings are probably just synonyms of the same accessions, it happens that the number of named variants keep increasing and eventually, it becomes necessary to group them in some way to indicate shared or individual attributes. It is essential to confirm whether the names are describing genetically distinct individuals and to find out how much diversity there is within these groupings. In the following review discussion of the *Musa* AAB "Apple" is made followed by the *Musa* AA "Muraru" dessert bananas found in East Africa.

Globally, the name "Apple" has been coined to name small fruited *Musa* AAB dessert bananas, probably because they are sub acid fruits (Simmonds 1953). These small fruited dessert bananas are widely distributed (India, Brazil, Hawaii, East Africa), but they are currently mainly for local consumption in areas of production (Stover and Simmonds, 1987). In East Africa, their share of the market is increasing and the "Apple" banana makes a major contribution to the region's economy as the demand is increasingly becoming high both locally and for export outside East Africa. Production in the region is by the small scale farmers who benefit from year round income as a result of the year round production. Current estimates of "Apple" bananas being imported to Europe from the region are said to be more than 50 tonnes per week. Kenya exported 16 tonnes of "Apple" bananas in 2007 worth (54,300 US$) or Kshs 3.8 million (2007 HCDA report). Uganda exported 120 tonnes in 2003 to UK and Holland at a value of 300,000 US$. Rwanda also exports "Apple" bananas. The supply of "Apple" bananas to European markets is still irregular. At the same time, there is need to export a standard type identified within the "Apple" banana group and one with a distinct name. Although

majority of the so called "Apple" bananas are used as dessert (consumed raw at ripeness and distinguished by the sweet flavour of the fresh fruit when ripe), a few members are used as juice or beer cultivars depending on type and culture (Karamura and Karamura, 1995).

In East Africa, *Musa* AAB "Apple" and *Musa* AA "Muraru" bananas are mostly grown in the traditionally known banana growing areas. In Kenya for example, "Apple" bananas are mainly produced in Central, Nyanza and Western Provinces while in Uganda "Apple" bananas are produced in Masaka, Mbale, Mbarara, Bushenyi, Mubende, Luweero and Wakiso districts. Other regions in East Africa are Rwanda, Zanzibar, Moshi, Bukoba, Morogoro and Usambara-Kilimanjaro mountain axis in the northeastern Tanzania (Baker and Simmonds 1951, Rossel and Mbwana 1991, De Langhe *et al*. 2002, Karamura *et al*. 2006). In Uganda they are commonly referred to as "Sukari" or "Sukari Ndiizi" and in Rwanda as Kamaramasenge." Table 6a shows a comprehensive list of the various "Apple" banana names and synonyms found in the region.

Evers (1992) while trying to characterise banana cultivars in Morogoro area had the same name Kisukari for several yellow small fruited "Apple" dessert bananas and in Morogoro, at least 8 cultivars belonging to different genomes can be called Kisukari or Sukari. Pillay *et al*. (2000, 2001) studied the Ugandan sample of Apple bananas confirming that the popularly known prolific Sukali Ndiizi of Uganda is a triploid rather than diploid. There are also the diploid AB, the Kisubi and Gisubi kagogo within the region. In their report, Karamura *et al*. (2006) stated that there were other bananas, including "Apple" bananas (*Musa* AB/AAB), Bluggoes, Monthan, and Pisang Awak *Musa* ABB, Gros Michel and Cavendish *Musa* AAA that are considered to be introductions of 1950s to East Africa.

Diversity of Apple bananas in East Africa

As already mentioned, the name "Apple" banana is indiscriminately applied to several *Musa* AAB and AB cultivars having sub acid fruits (Simmonds, 1953), while on many occasions, the name is also synonymously used with the name Lady's finger which is applied to almost any banana with small fruits (Simmonds, 1953). In marketing, the "Apple" banana is also wrongly referred to as "baby" banana, a name also used for the smaller thin skinned yellow AA Sucrier bananas e.g. Datil. It is very difficult to distinguish morphologically the different types of "Apple" bananas especially based on fruit traits alone. While majority of the so called "Apple" bananas are characterized by small, short and plump fruits, slender, green

yellow pseudostem with slight or no blotches, some differ in the texture of the ripened fruits, yet others differ in the appearance of the fruit skin when the fruit is green. Table 6a shows a list of *Musa* AAB and AB dessert bananas assembled according to similarity with their various names in different locations in East Africa. Figure 6a shows the phenogram from UPGMA clustering using Jaccard's similarity coefficient for 51 AAB "Apple" accessions and their AAAB derivatives based on microsatellite markers (Onyango 2007). In the study, Onyango (2007) found that the AAB "Apple" sub-group of dessert bananas is heterogeneous, and the differences among the taxa within AAB "Apple" sub-group was less than that between the AAB "Apple" and AAB plantain sub-groups. Four distinct AAB "Apple" dessert banana taxa were recognized using molecular and morphological data (Onyango, 2007). These are *Musa* AAB "Prata," Musa AAB "Mysore," Musa AAB "Silk," and Musa AAB "Sukari Ndizi" (now referred to Kamaramasenge) (Figure 6a), and the Cytometric data confirmed that the four were triploid AAB bananas. The "Sukari Ndizi" was the most homogeneous of these taxa and is clearly differentiated from the others with the same genomic composition.

Table 6a: Apple group cultivars in East Africa

***Musa* AAB subgroups Sukali Ndiizi, Prata, Silk and Mysore**				***Musa* AB genomic group**
AAB "Sukari Ndizi"	**AAB Prata**	**AAB Silk**	**AAB Mysore**	**AB Kisubi**
Cultivar/ synonym	Cultivar/ synonym	Cultivar/ synonym	Cultivar/ synonym	Cultivar/ synonym
Kamaramasenge (ITC127)				
Kamaramasenge (Butare)	Exera	Silk (ITC 348)	Mysore	Kisubi (Ganda)
Kisukari (Kisii)	Soth	Manjano	Pisang Ceylan ITC 144 (India)	Barwokole (Toro)
Wangae (Kiambu)	Manyatta	Mboki (Msukari)	Kisukari ratong (Luo)	
$Embu_1$ (Embu)	Kifutu	Ungoye sweet	Sukari red	
Kakamega (Kakamega)	Kusukari Giant (Kisii)	Manzano	Ndiizi w'emiti (Soga)	
Sukari Ndizi (Kiswahili)	Kisukari Kubwa (Morogoro)	True Apple	Wangae red	
Sweet banana	Apple	Figue Pome Geante (ITC 769)	Ndiizi omumyufu (Ganda)	Kipakapaka Ndogo (Morogoro)

***Musa* AAB subgroups Sukali Ndiizi, Prata, Silk and Mysore**				***Musa* AB genomic group**
AAB "Sukari Ndizi"	**AAB Prata**	**AAB Silk**	**AAB Mysore**	**AB Kisubi**
Sukali Ndiizi (Ganda)	Mutsari (Butare)	Kipakapaka Kubwa (Morogoro)		Kipukucha (Morogoro)
Kabaragara (Ganda)	Rajapuri	Kisukari Kavu ? (Morogoro)		Mineke?
Yellow (Nkore)	Figue famillia (ITC743)	Kisukari Chachu ? (Morogoro)		Kasukari (Bwamba)
Obwenvu (Ganda)	Foconah (ITC649)	Kipukucha (Morogoro)		Subi
Ladys finger (English)	Prata (ITC207)	Kimbani (Mbeya)		Kasubi
Sukari (Kisumu)	Prata (Butare)	Kipukusa (Zanzibar)		Gisubi
Guindi (Kiambu)	Lady Finger (ITC582)	Sports of silk (ITC122)		Gisubi kagogo
Kanana	Lady Finger South Johnson (ITC583)	Ney Poovan (ITC459)		
Bunana	Improved Lady Finger ((ITC336)	Guindi (Butare)		
Kasukari	Kijakazi (Zanzibar)	Pukusa (Zanzibar)		
Kingala 1 (ITC737)	Prata ana (ITC962)	Kipukusa cha Java		
Yangambi2 (ITC1275)	Brazilian (Tall and short)			

Source: Shepherd, 1957; Evers, 1992; Karamura and Karamura, 1995; Onyango; 2007

Figure 6a

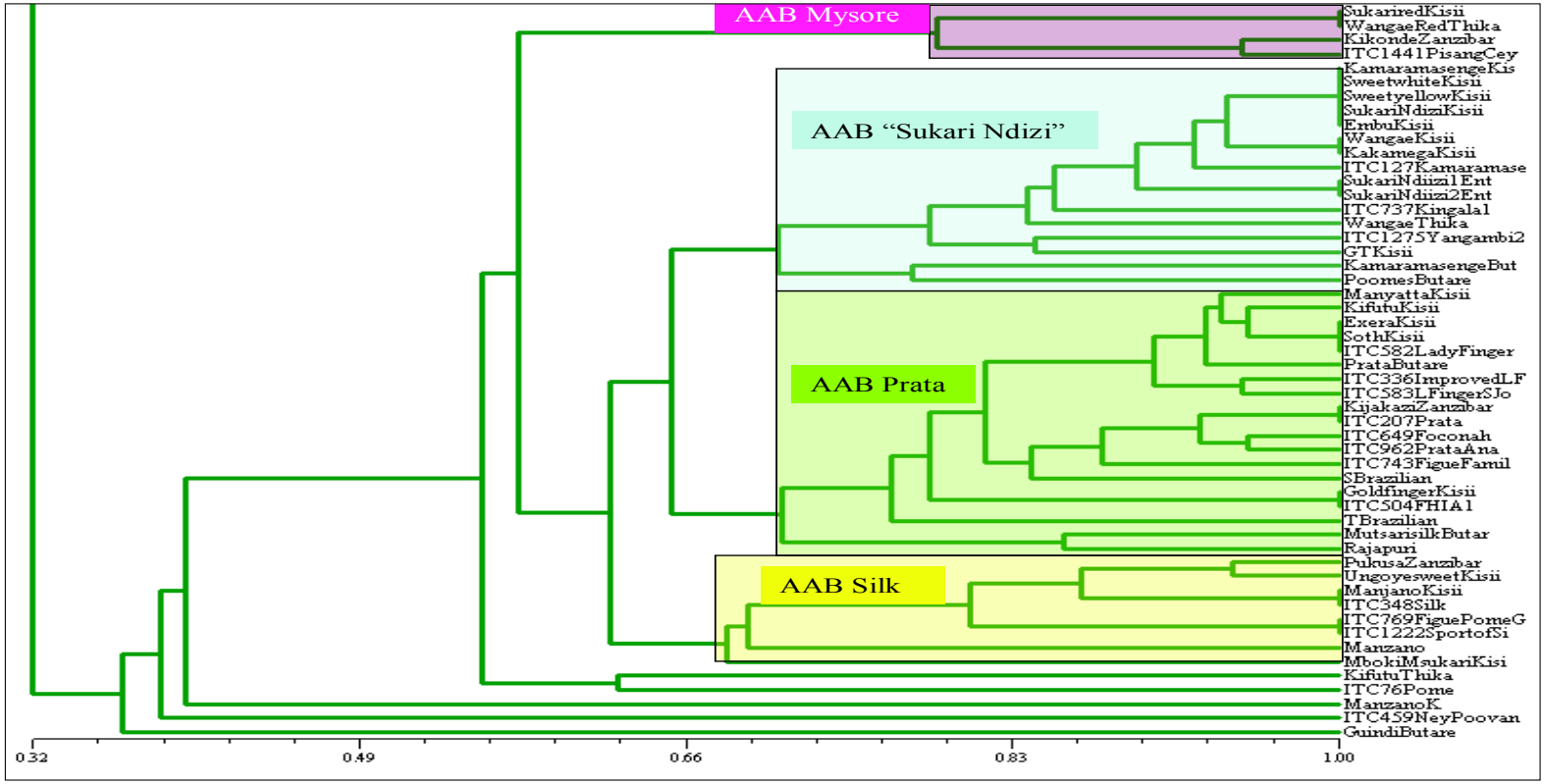


Figure 6a: Phenogram from UPGMA clustering using Jaccard's similarity coefficient for 51 AAB "Apple" accessions and their AAAB derivatives based on microsatellite markers. Cophenetic value 0.900.

The AB diploid accessions namely Safet Velchi and Kisubi are also small fruited and have a close fruit resemblance to their triploid counter parts (Figure 6a). These AB accessions, are more closely related to the AAB Silk (Onyango 2007). The assumption has been that "Sukari Ndizi" and Kisubi were both AB diploids and closely related or belonging to the same clone. Stover and Simmonds (1987) listed the principal clones of AAB group as: Plantain sub-group, Pisang Kelat, Pisang Raja, Mysore, Maia Maoli, Silk, and Pome. He noted that Pisang Raja (probably closely related to Rajapuri) is not known in East Africa, but Mysore is known as Kikonde in Zanzibar, while Pome is represented by Kijakazi in Zanzibar and Silk is represented by Kipukusa and Sukari in East Africa. Thus Stover and Simmonds (1987) grouped the "Sukari Ndizi" and Silk in one taxon. "Sukari Ndizi" was neither an AB genotype nor a member of the AAB Silk taxon. The study of Onyango (2007) indicated that "Sukari Ndizi" dessert bananas constitute a separate distinct cluster within the AAB "Apple" subgroup, separate from AAB Silk, AAB Mysore, and AAB Prata/Pome, and also AB Safet Velchi taxa. Table 6b shows data of some important horticultural traits among the various *Musa* AAB "Apple" groupings.

The AAB "Sukari Ndizi" is a homogeneous taxon within the AAB "Apple" sub-group thus justifying it being a distinct taxon separate from the other AAB "Apple" dessert bananas. It is possible that AAB "Sukari Ndizi" was introduced with other bananas in the 1950s and it has become widely distributed in the region. Other Reference accessions from Bioversity International namely ITC 1275 Yangambi no2 and ITC0737 Kingala1 fall within the "Sukari Ndizi" cluster (Figure 6a). The small variability within East African "Sukari Ndizi" accessions indicates they are, indeed, probably just a recent introduction to the region in comparison with AAA East African Highland bananas that have diverged into five distinct clone sets (Karamura 1998).

Morphological description of the East African AAB "Sukari Ndizi" in relation to other Musa AAB "Apple" dessert bananas

The following key traits describe the East African AAB "Sukari Ndizi" grouping:

- cream compound tepal basic color without pigmentation
- no blotches on the leaves of water suckers
- fruits ≤ 15cm in length with short pedicel
- green yellow pseudostem with brown/ rusty brown pigmentation

The East African AAB "Sukari Ndizi" banana is distinct from the other AAB "Apple" dessert bananas groupings i.e. the AAB Prata, the AAB Mysore and the

AAB Silk. The AAB "Sukari Ndizi" are small-fruited triploid natural hybrids of *M. acuminata* and *M. balbisiana* Colla having a genomic composition of these two at a proportion of 2:1, respectively. The ploidy level and genomic composition have been confirmed (Onyango 2007) with the flow cytometry as a triploid. They have an intermediate leaf habit that may be mistaken for an erect habit especially when they are growing in very fertile soils where they may grow tall (>3 metres) and slender (Figure 6b). They have a cream compound tepal basic color without pigmentation, in clear contrast with the pink/ pink-purple pigmentation of the Mysore, the Silk, the Prata taxa, and the Kisubi. The "Sukari Ndizi" have short pedicel and the ovules are arranged in 2 rows characteristic of *acuminata*. Unlike the Mysore and the Prata that have water suckers that have purple blotches "Sukari Ndizi" has no blotches on the leaves of water suckers. They are less robust than Prata and their pseudostem is generally straighter than the Silk (which have a slightly arched pseudostem). Although all four AAB "Apple" banana taxa, the Prata, Mysore, Silk and "Sukari Ndizi," have a bare rachis at the time of fruit maturity, the "Sukari Ndizi" rachis is always bare even just a few weeks after flowering. In contrast to the Prata that have longer >20cm waxy silvery fruits, the "Sukari Ndizi" has smaller fruits ≤ 15cm in length with short pedicels. Plants have slender to normal pseudostem that are of medium to tall height depending on the stage of crop growth and also on the fertility and rainfall of the growing conditions. Pseudostem color is green yellow with rusty brown pigmentation. The petiole margins of the "Sukari Ndizi" are curved inwards, a characteristic of *balbisiana*. Mysore can be distinguished from "Sukari Ndizi"by having medium long fruits ≥16≤18 that are slightly waxy and a darker green pseudostem with black pigmentation and purple midrib, and a purple cigar leaf. The "Sukari Ndizi" has green cigar leaf and a light green midrib.

The "Sukari Ndizi" has an average bunch weight of 8kg with an average of 8 hands per bunch, and a mean of 100 fruits per bunch (Table 6b). Each hand has an average of 12 fruits each weighing 80grams and the average weight of the hand is 1kg. The fruit is green while mature but unripe and turns yellow when ripe. Pulp color is cream while mature green and yellow when ripe. Unlike fruits of most of the Silk sub-group that have pulp that is dry with hard brownish parts in the flesh, "Sukari Ndizi" has firm textured spotless uniform cream pulp when flesh. Although the "Sukari Ndizi" fruits appear to resemble those of the Mysore at maturity and when fully ripe, the fruit "Sukari Ndizi" has thicker peels, a more firm texture and an acidic taste, unlike the Mysore fruits that have a sweeter taste. Silk banana fruits are non-acidic and sweet.

Figures 6b, 6c, 6d, 6e, and 6f are pictures of representative accessions of AAB Sukari Ndiizi, AAB Prata, AAB Mysore, AAB Silk and AB Kisubi respectively.

Table 6b. Important horticultural traits among Musa AAB "Apple" taxa in Kisii, Kenya

Grouping	Days to Flowering	Days to Harvest	Flower to Harvest	Plant Height	Plant Girth	Total Leaves	Leaves at Flowering	Leaves at Harvest	Leaf Area (cm^2)	Total
"Sukari Ndizi"	380d	550e	169b	2.43c	43.7d	33c	12c	7c	9248b	16a
Prata	451b	652b	200a	3.24a	52.9b	39a	16a	11a	10529a	15ab
Silk	429c	577d	147c	2.52c	45.22d	38b	13b	5d	8226c	13bc
Mysore	511a	670a	162bc	3.26a	48.53c	40a	14b	9b	9750b	10cd
GT	451b	603c	152c	2.83b	54.9a	37b	14b	9b	10509a	9d
Mean	422	594	171	2.7	47.5	36	13	8	9503	15
CV	7.2%	4.5%	15.9%	5.7%	5.8%	7.8%	11.9%	16.9%	9.5%	24.6%
"Sukari Ndizi"	8.6d	7.8c	8b	12c	97c	0.974c	79d	13.8d	11.9b	
Prata	15.7a	16.8a	7c	13b	93c	2.152a	165a	21.5a	14.7a	
Silk	8.2d	7.7c	7c	11d	72d	1.043c	93c	16.5b	12.2b	
Mysore	12.8c	14.0b	13a	18a	225a	1.068c	62e	15.5c	10.8c	
GT tetraploid	14.3b	14.1b	8b	13b	109b	1.485b	118b	15.9bc	14.4a	
Mean	11.1	11.0	8	13	100	1342	106	16.7	12.8	
CV	13.3%	13.6%	10.1%	8.4%	13.5%	15.3%	13.9%	9%	8.3%	

Means in the same column with the same letter/s coding are not significantly different, according to DMRT at p≤0.05.

Fig. 6b: Some morphological diagnostic traits of AAB "Sukari Ndizi" plant, ripe fruit, male bud and water sucker leaf



Figure 6c. Some morphological diagnostic traits of AAB "Prata" plant, male bud, cigar leaf, and water sucker leaf



Fig. 6d: Some morphological diagnostic traits of AAB "Mysore" plant, male bud, cigar leaf and water sucker leaf



Fig. 6e: Some morphological diagnostic traits of AAB "Silk" plant, male bud, green and ripe fruit



Fig. 6f: Some morphological diagnostic traits of AB "Kisubi", plant, male flower, ripe fruit and leaf petiole



The *Musa* AA 'Muraru' dessert banana

The AA "Muraru" dessert bananas are surprisingly large fruits (Fig.6h) for a diploid banana. Preliminary observations show that AA "Muraru "bananas are slow to mature and when the fruits are ripe and ready for eating; they remain green to green yellow (Onyango 2007). These short comings probably are the main contributing factors to their lack of export market. In East Africa where they have cultural value in some communities, they are mainly grown for local consumption in production areas. They are locally known by the following names: Mshale, Mjenga, Mulalu, Muraru, Mlelembo, Makhughu, Njuru, Kamunyilya, Sucrier, Lady's finger, and Mraru.

The cultivated diploid AA bananas have not been fully classified. However, Daniells *et al*. (2001) placed some of the cultivated AA bananas into 4 sub-groups, i.e., (1) Sucrier, e.g., Pisang Mas, (2) Pisang Lilin, e.g., Pisang Lilin, (3) Inamibal, e.g., Inamibal, and Pisang jari buaya, e.g., Niukin. Simmonds (1966) also recorded several distinct populations within *M. acuminata* namely macrocarpa, siamea, malaccensis, banksii, and burmannica, with outliers in Hawaii, Pemba, and Samoa. Simmonds (1966) stated that most edible diploids evolved entirely from the wild *M. acuminata* AA genome by becoming seedless. Additionally, several sub-species and many parthenocarpic landraces (Lysak *et al*. 1999, Ude *et al*. 2002) have been recognized within *M. acuminata*. The various origins of cultivated AA diploids, which are themselves basic to the evolution of the triploid cultivars, can only be speculative at the present time (Shepherd 1990). Efforts to classify *M. acuminata* into sub-species are difficult because of the occurrence of hybrids of *M. acuminata* (natural and artificial) and other sympatric sub-species. Since the AA genome is a variable species with several different sub-species (Simmonds and Weatherup 1990), the different edible diploids may have originated independently and more than once. Apart from being seedless, the edible diploids remain within the morphological range of their wild parents (Pickersgill 1986). It is possible that crosses between the different *M acuminata* sub-species produced some of the cultivated diploid AAs resulting in the variation of the diploid AA found in different geographical regions such as Papua New Guinea (PNG) and East Africa. Mutation may have added to the diversity seen in these regions. The diploid bananas, wild and cultivated, are presently much less widespread than the cultivated triploids (Jenny *et al*. 2003). Jenny *et al*. (2003) noted that despite the large number of cultivated diploid clones known, no further subgroups have been established.

Determination of the distinctness of East African AA "Muraru"

Onyango (2007) found that the East African AA bananas sourced from Arusha, Tanzania, and Thika and Kisii, Kenya, identified initially by morphological characteristics as belonging to AA "Muraru," were closely related and formed a homogenous cluster based on microsatellite markers and morphological traits. From that study, the AA "Muraru" cluster was separate and distant from other AA diploid bananas studied (Fig. 6g) an indication that they were a distinct group of AA diploids with a natural grouping separate from the other AA bananas. Ploidy determination, using flow cytometry confirmed that "Muraru" were AA diploids (Onyango, 2007). In the same study there was high similarity between the "Muraru" taxon and the commercial triploid dessert bananas. It was hypothesized in the study that AA "Muraru" bananas are of an origin that is distinct from the other AA diploid bananas which were studied, however, the AA Kipaka from Zanzibar, proved to be closest to the other AA diploids, such as Sucrier, Maia Hapai, ITC0392 Datil, ITC0714 Kirun, and ITC1358 Ngu. Kipaka was probably of similar origin with these latter accessions. Simmonds and Shepherd (1955) recorded *acuminata* outliers found in Pemba (along the coast of East Africa), and Hawaii and Samoa (*banksii* sub-species). In Pemba, the Kipaka was phenotypically not unlike the sub-species *malaccensis*, but, in crossing behavior, seemed nearer to an Indonesian form of the species. Zanzibar is very close to Pemba, and Kipaka is probably the AA outlier mentioned by Simmonds and Shepherd (1955).

In his book, Stover and Simmonds (1987) indicated that the only important edible diploid AA *acuminata* is the Sucrier favored for its sweet, thin-skinned fruit. In the morphological appraisal (Onyango, 2007), AA Sucier had many features similar to AA "Muraru," especially the male bud and flower. But based on microsatellite markers the two clones had low similarity and were not closely related. The Sucrier fruits are also much smaller than those of "Muraru." In the studies carried out by Onyango, 2007, the AA "Muraru" was distinguished from other diploid and triploid dessert bananas. The Kipaka or Paka, sourced from Zanzibar on the coast of East Africa, was found to be a Sucrier but the "Muraru" clones from the interior of East Africa were confirmed as a separate sub-group of AA bananas. Simmonds (1966) noted that the *M. acuminata* species is extremely variable and the variability is geographically discontinuous, and *M. acuminata* also has morphologically distinct populations that occupy distinct geographical areas and breed mainly with in themselves. In the case of the "Muraru" accessions,

the AA Muraru–Mucuuru are grown on the Mount Kenya foothills (Karamura *et al*. 2006). The separation of the diploid AA "Muraru" from other diploid *M. acuminata* (Onyango 2007) and the formation of one cluster was an indication that the "Muraru" was indeed a distinct AA diploids and formed a homogenous group.

Key traits that describe East African AA "Muraru"

- erect leaf habit, edge of petiole margin with pink-purple color line
- fruits lengthily pointed and shiny green
- fruits ≥ 20 cm long and green to green-yellow when ripe
- normal pseudostem aspect with medium green color having brown-black pigmentation
- bract external surface is purple brown and no wax
- blotches on the leaves of water suckers

Description of the AA Muraru bananas

The AA Muraru are a medium- to long fruited-diploid of *M. acuminata* Colla only. Unlike most diploid AA bananas that have small fruits, the "Muraru" AA do have fruits that may surpass those of some Cavendish and Gros Michel accessions in size. They have an erect leaf habit that shows their ploidy level, and they grow tall (>3 meters), with a normal pseudostem. They have a cream colored compound tepal with brown pigmentation, and a green ovary basic color. The fruits have short pedicels. Unlike the East African highland banana, they have purple blotches on the leaves of water suckers, just like the Cavendish and Gros Michel. For most "Muraru," the rachis has few neutral flowers, but some have persistent withered bracts on the rachis.

The "Muraru" fruits are long and slender (>20 cm) (Table 6c) relative to other diploid bananas, and have gradually tapering points. The mature unripe fruits are green and shiny and they remain green yellow to yellow when ripe, unlike the Gros Michel and the Cavendish dessert bananas which become golden yellow. The pseudostem color is medium green with a little rusty brown to black pigmentation. A bunch of the "Muraru" weighs, on average, 16kg, with a mean of 8 hands that weigh 2kgs: There is an average of 16 fruits per hand, each weighing 125grams. The pulp color is cream while mature green, and cream to ivory when mature and ripe. Unlike the fruits of the Pisang Mas AA that is sugary, the "Muraru" has a mild, slightly tasty or bland predominant taste. The fruit of the "Muraru" has thicker peels and a firmer texture than the Pisang Mas.

Table 6c: Bunch weights, potential yields and fruit traits of the *Musa* AA "Muraru" banana accessions grown in Kisii, Kenya

Accession	Bunch weight (Kg)	Yield (tons ha^{-1} yr^{-1})	Hand weight (grams)	Fruit weight (grams)	Fruit length (cm)	Fruit circumference (cm)
TT2	17.6^{cd}	16.1^{bc}	2159^{b}	168.5a	24.6^{b}	13.1^{bcd}
Muraru	23.7^{a}	20.7^{a}	2347^{a}	179.7a	25.6^{ab}	13.3^{abc}
Mraru Mlalu	15.8^{cd}	14.5^{bc}	1908^{cd}	151.1b	24.8^{b}	12.7^{cde}
Muraru Mshare	18.3^{c}	16.4^{b}	2165^{b}	169.3a	26.2^{a}	13.5^{ab}
Njuru	12.8^{ef}	11.8^{de}	2057^{bc}	151.6b	19.2^{e}	13.2^{abcd}
Muraru green bell	10.9^{f}	9.6^{f}	1749^{d}	133.1c	22.8^{c}	12.3^{e}
Muraru red bell	15.7^{cd}	14^{cd}	1995^{c}	149.3b	22.7^{c}	12.3^{e}
Kamunyilya	15.0^{de}	13.9^{cd}	1968^{c}	151.3b	21.2^{cd}	13.8^{a}
Maji maji	20.9^{b}	18.6^{a}	2337^{a}	171.7a	22.1^{cd}	13.1^{bcd}
Makyughu	13.1^{ef}	11.2^{ef}	1908^{cd}	149.7b	22.4^{c}	12.5^{de}
Critical range	2.85	2.455	182	16.08	1.189	0.7571
Mean	16.4	14.7	2063	157	23	13
CV	18%	17.4%	9.2%	10.6%	5.4%	6%

Means in the same column with the same letter/s coding are not significantly different, according to DMRT at p≤0.05.

Fig. 6g: Phenogram from UPGMA clustering using Jaccard's similarity coefficient for 54 accessions of AAA and AA groups based on microsatellite markers. Cophenetic value = 0.900.

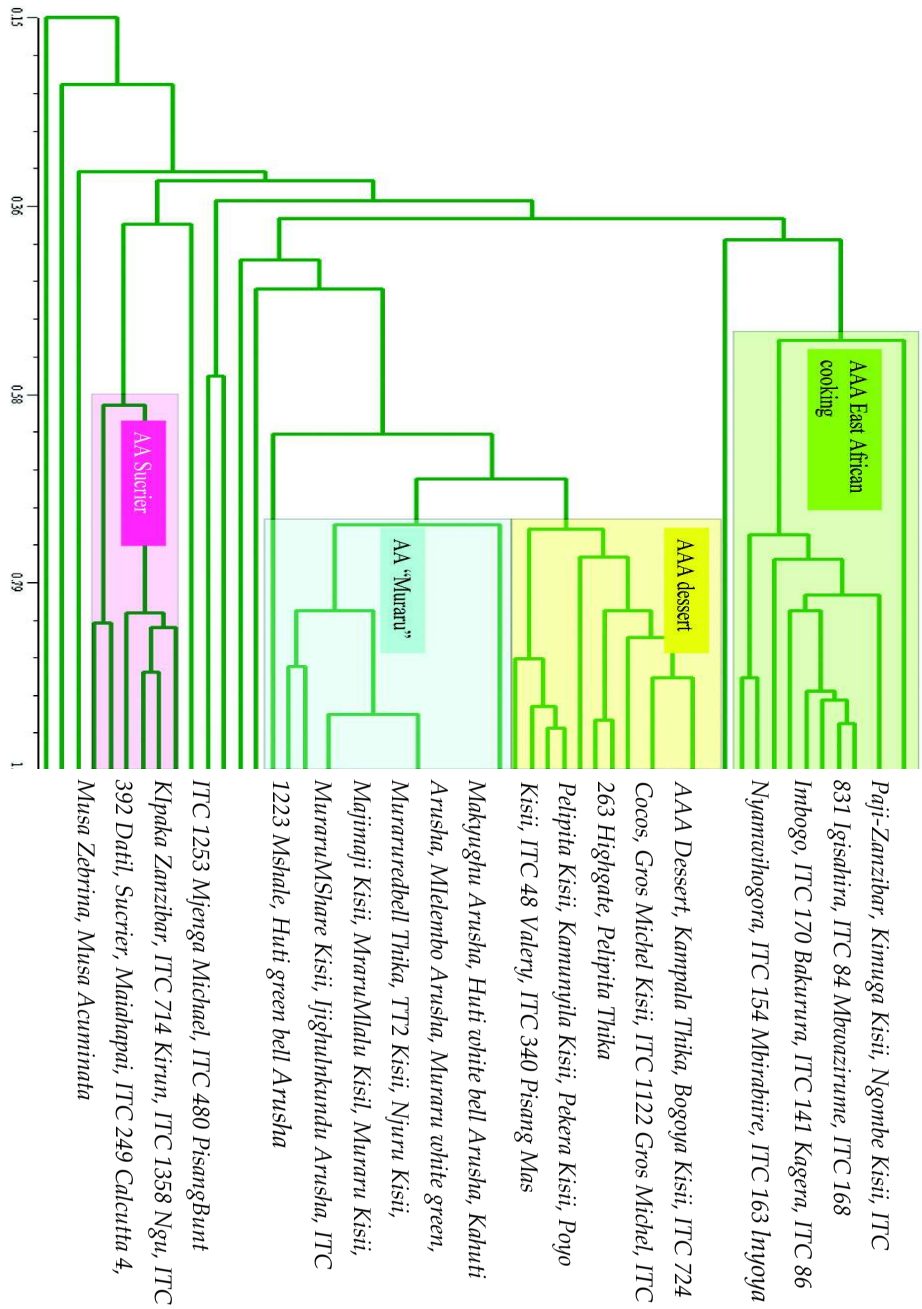


Fig. 6h: Some diagnostic morphological traits for *Musa* AA "Muraru", plant, buds and ripe fruit



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7

Musa ABBs and some introduced hybrids

Musa ABB cultivars in East Africa

Karamura Deborah and Muhwezi Robert

In East Africa, there are six commonly occurring cultivars belonging to *Musa* ABB genome group of bananas; two in subgroup Bluggoe, two in Pisang Awak, and two in Monathan subgroups. There are approximately 13 to 14 other clones belonging to ABB group but these have just been introduced in the East African collections to assess their performance and then popularise them among farmers.

Based on their fruits and the vegetative characteristics, cultivars in *Musa* ABB group are distinctively waxy. The upper sheaths, petioles, fruits, and male buds are moderately to extensively waxy. The pseudostems are light and bright green with hardly any blotches. The fruits are medium (10-15cm) long, almost perpendicular to rachis and with almost blunt shaped tips. The clones in this genome group display good environmental tolerance; they are elastic with respect to varying ecological conditions. The cultivars are reported to be resistant/tolerant to black Sigatoka, weevils and nematodes, susceptible to Fusarium wilt and now very recently discovered to be very susceptible to bacterial wilt. Although commercial prospects with beverage industry are high in East Africa, the cultivars succumb to the recent deadly bacterial wilt disease. The synonyms of these groups of bananas are shown in table 7.

Monthan

Pisang Awak

Fig. 7a: Kisubisubi



Fig.7b: Mussa



Bluggoes

Fig. 7c: Kivuvu



Fig. 7d: Kidhozi

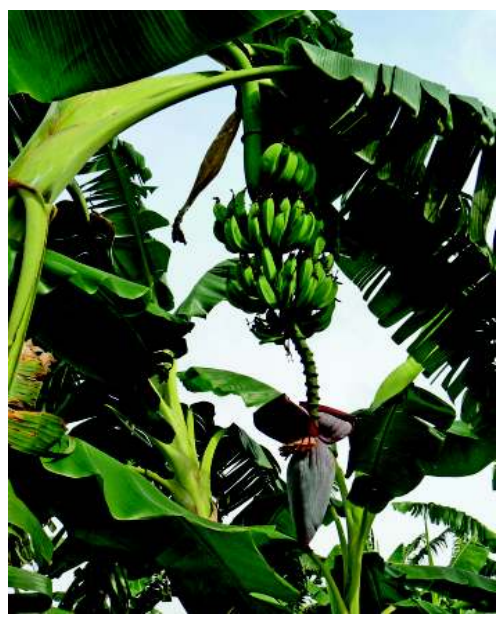


Fig.7e: Kayinja	Fig. 7f: Saba
	

Tabel 7: Musa ABB-Cultivars and their synonyms

Subgroup	Name in Uganda	Name in other East African country
Bluggoe	Kivuvu (also in Rw and Br.) Pepepe , Kipepepe (Bwamba), Entenga (Nkore), Bokora (Toro), Manjayi , Bogogo -Liwanga (Gisu)	Bokoboko (K, Tz), Kibutu, Kibunda, Mbuu (K) Kikonjwa, Kikojozi, Kinyaijwe, Kitegombwa, Koroboi, Mkojozi (Tz) , Kipepepe, Naluvu of Kamanyola, Nyaruvu (DRC) Halale, Halali (Tz) , Mbokoboko (Tz), Mngazija (Tz), Mgomba (Dodoma), Punda (Pemba) Ikonosi (Moshi), Kisubi Katarina (DRC)
	Kidhozi Bogogo -mumaali (Gisu), Bimusa.	Yakobi (DRC), Kijosi, Same names as above are applied to this in a number of locations.
Monthan	Kisubisubi waxy	Kisubi Musa (DRC) Ndithi, Mbuu (K), Ngazija Kubwa, Bokoboko Kubwa, Koroboi (Zanzibar)
	Kisubisubi non waxy	Same names as above are applied to this one.

Subgroup	Name in Uganda	Name in other East African country
Pisang Awak	Mussa (waxy) Nairobi (Gisu), Itokebusa (Soga), Serere (Gisu), Ndeka , Balukule (Toro),	Kisubi (Tz) Bogobogo (Br), Mugomoza, Mugomboza (DRC), Nyeupe, Muarusha, Juma Mhuni, Kabuu, Kimuhuu (K), Gulutu (Tz.), Halale (Mbeya), Kijivu (Arusha), Kipungara (Moshi), Kisukari
	Kayinja non waxy	Kisubi (Tz). Same names as above are applied to this one.

NB: The name Benja or Henja is used in Rwanda to describe either Bluggoes or Pisang Awak.
(Br) - Burundi
(DRC) - Democratic Republic of Congo
(K) - Kenya
(Tz.) - Tanzania
Ref: Shepherd, 1975

FHIA hybrids in East Africa

Karamura Deborah

Bananas in East Africa are susceptible to a number of diseases like the serious black Sigatoka (*Mycosphaerella fijiensis* Morelet) and Panama Wilt (*Fusarium oxysporium* Schlecht. F. *cubensis* (E.F.Sm) Synder and Hansen) and do succumb to pests like the banana weevil (*Cosmopolites sordidus* (Germ.) and nematodes like *Rodopholus similis* (Cobb.). The diseases and pests have caused decline in production and yield for more than 20 years. Bananas are not only susceptible to diseases but their productivity and ecological adaptations are very low. Lack of banana cultivars with resistance/tolerance to diseases, pests and drought as well as with no superior characteristics had caused national programmes in East Africa to introduce new banana hybrids with resistance. These new cultivars have now been evaluated here in East Africa for high yields, resistance/tolerance to diseases, pests and water stress (drought) and for consumer acceptability (Nowakunda, et.al. 2000, Rosales, 2008). The following new cultivars have been found to have good qualities and their synonyms are attached.

Fig 7g: FHIA 01 [Goldfinger, Goldi, Kabana 1] AAAB



- High yielding [bunch weight up to 65 kg]
- Highly resistant to black sigatoka and burrowing nematodes
- Resistant to Fusarium wilt race 1 and 4
- Tolerant to banana weevil and drought
- Multipurpose : cooking, juice, dessert. Harvested fruits have long green life

Fig. 7h: FHIA 02 [Monalisa, Mbonwa] AAAA



- Highly resistant to black sigatoka, nematodes and weevils
- Resistant to yellow sigatoka
- Susceptible to Fusarium race 1 and race 4
- Use: dessert, similar to Cavendish but has short harvest green life. Fruits keep dropping off as soon as it rippens.

Fig 7i: FHIA 03 (Bahati, Kabana 2). AABB



- High yielding (bunch weight up to 60 kg)
- Tolerant to black sigatoka, Fusarium wilt
- Tolerant to banana weevil and drought.
- Multipurpose: very high juice content (76.5% w/w): dessert banana, cooking banana

Fig.7j: FHIA 17 (Kabana 3) AAAA



- High yielding (bunch weight up to 70 kg)
- Highly resistant to black sigatoka and Fusarium wilt.
- Tolerant to banana nematodes and drought
- Use: dessert

Fig. 7k: FHIA 21



- Resistant to black sigatoka and fusarium Wilt 1 and 2.
- Found to be susceptible to banana streak virus (BSV) , banana weevil (Uganda) and to two of the Nematodes of major importance in this crop: *Radopholus similis* and *Pratylenchus coffeae*.
- Use: roasting banana, excellent plantain flavour but relatively short green life

Fig. 7l: FHIA 23 (Kabana 4) AAAA



- High yielding (bunch weight up to 70 kg)
- Resistant to black sigatoka and Fusarium wilt race 1.
- Tolerant to banana weevils and drought
- Use: Dessert banana

Fig. 7m: FHIA 25. AAA



- Highly resistant to black Sigatoka.
- Used for beer

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8

Spatial patterns of farmer-named and distinct banana cultivar diversity in the East African region

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Introduction

Agriculturalists in the past counted much on the intrinsic genetic diversity in their crops, that allowed these crops to adapt to new environments and climates in addition to the success of human colonization across the globe. Farmers and breeders today value genetic diversity of crops in the same way. Many improved cultivars with potential high impact produced by present-day breeding programmes have a long genealogy involving several wild species and traditional landraces. 'Calcutta 4', (*Musa* AA) a wild species from South East Asia, for instance is the best known source of resistance to black Sigatoka, hence has been widely used in the current breeding programmes. Banana genetic diversity is priceless and efforts are being made to conserve it in different countries around the world. A large proportion of the cultivated banana diversity is maintained in International Musa germplasm collections as well as regional and national collections. However, this diversity, and frequently the knowledge associated with it are becoming difficult to conserve. As we have already seen, all the banana groups suffer from synonym/homonym nomenclature, which may limit effective conservation efforts, exchange of germplasm, commercial and research use. In addition, it is also very difficult to know how representative each of these groups in the region of East Africa is, as well as in national collections. While diversity can be described by local names and genome groups, allocation of numbers, their distribution and attributes within a particular environment can also be used to work out synonymy and homonym. In the East African region, most of the Musa diversity and conservation studies have been done on the East African Highland bananas (EAHB) (*Musa* AAA). Cultivars are described by local names of farmers

but it is not clear whether local names stand for distinct clones. Little has been done on the early introductions and yet still much less is known about the Meru – Kilimanjaro series of clones in the East African region. In this paper, it is the distribution within a particular environment that will define the spatial patterns of farmer-named and distinct banana cultivar diversity in the East African region. The objectives of the following presentation is to show how spatial tools can be applied to map and describe banana cultivar diversity and to assess the extent to which farmer-named and distinct banana cultivar differ.

Materials and methods

Data on farmer-named and distinct banana cultivars were extracted from the banana baseline information database (INIBAP,2003). Banana cultivars were recorded by name as given by the farmer and/or interpreted as distinct by the person recording farmer-named cultivars. Using a provisional checklist (Karamura and Karamura, 1994) and expert knowledge, the farmer banana cultivar "names" were recorded as distinct cultivar names. Data was then aggregated at district level for Burundi, Kenya, Rwanda and Tanzania and county level for Uganda. Districts and counties formed the administrative mapping units respectively. All the cultivars listed for each of the districts and counties were assigned coordinates of the centroids for location mapping. This is an oversimplification or a limitation that does not capture the intra-district/county diversity by lumping cultivars within the geographic centre of the district/county. This data was then imported into DIVA-GIS 4, a geographic information system for the analysis of biodiversity data for spatial analysis. The 4479 data points were gridded to analyse richness (number of observations/distinct classes), diversity (diversity indices) and richness complementarity using simple point to grid procedure. Grid/cell size was set at 0.5 decimal degrees for the extent of the principal banana production areas. This was done for both farmer-named and distinct cultivars for the total named cultivars. Grid calculator function was used to do the comparisons. Examination of the relation between the number of observations and the calculated diversity was done to infer the reliability and hence the significance of the results from the present data.

Results and discussion

Figure 8a shows the areas of concentration of cultivar collections (maroon-red grids/cells) which include parts of the Lake Victoria crescent, south-western mid-altitude/grass-farm lands in Uganda; northern and western fringes of the

Kagera region in Tanzania; eastern and northern fringes of Kibungo (eastern highlands) and Byumba areas respectively, including central Lake Kivu basin. Western-Kigoma and areas like southern highlands in Tanzania among others, are where additional collection is implied. Up to 156 observations were recorded in a grid cell indicating areas of banana cultivars' richness. Richness is the number of cultivars (or other units) present in a specified area and/or time. It expresses amount but not relative abundance. It is a term commonly used as a measure of species diversity, but technically only one aspect of it. Richness could also be the number of cultivars' or groups' of desired characters observed in an area (Fig. 8b number of observations).

Fig. 8a. Areas of concentration of cultivar collections (maroon-red grids/cells).

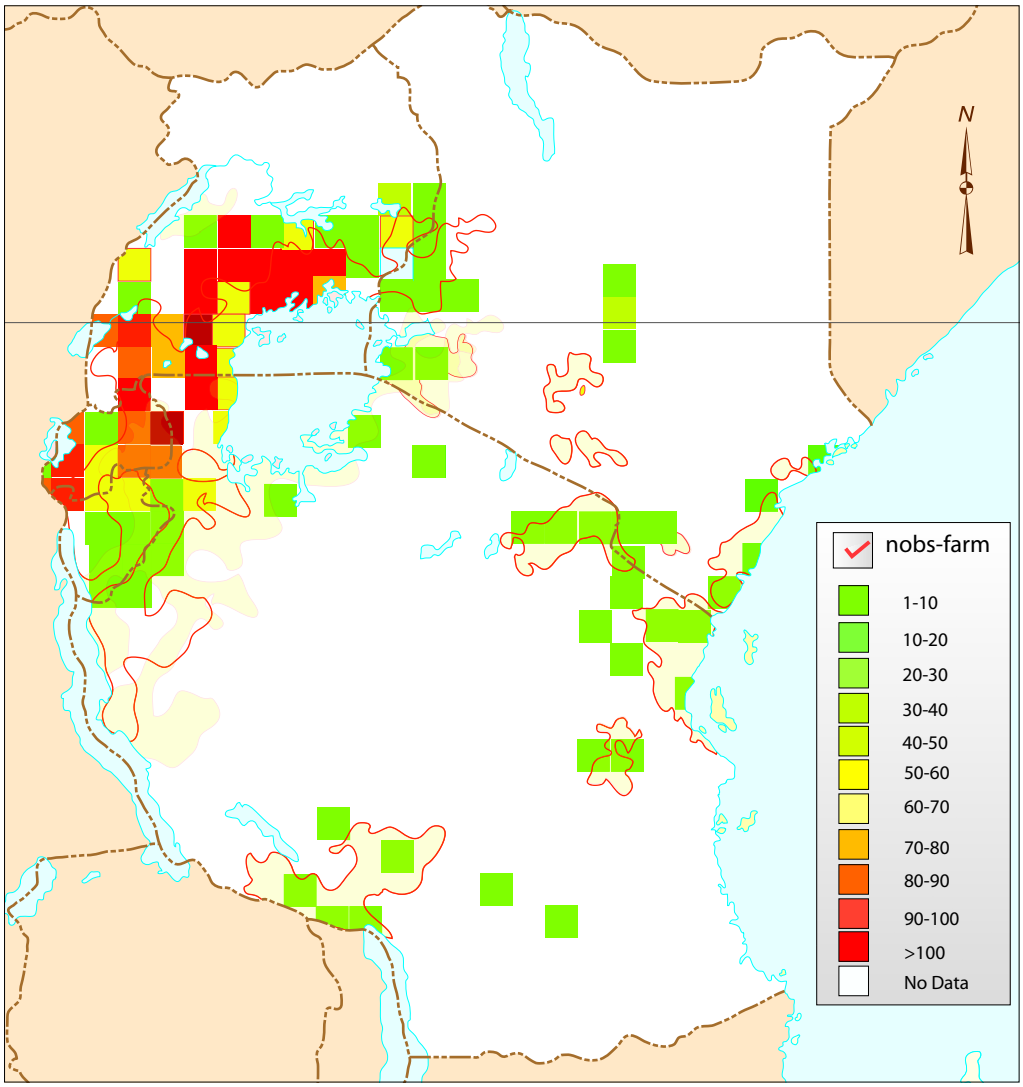
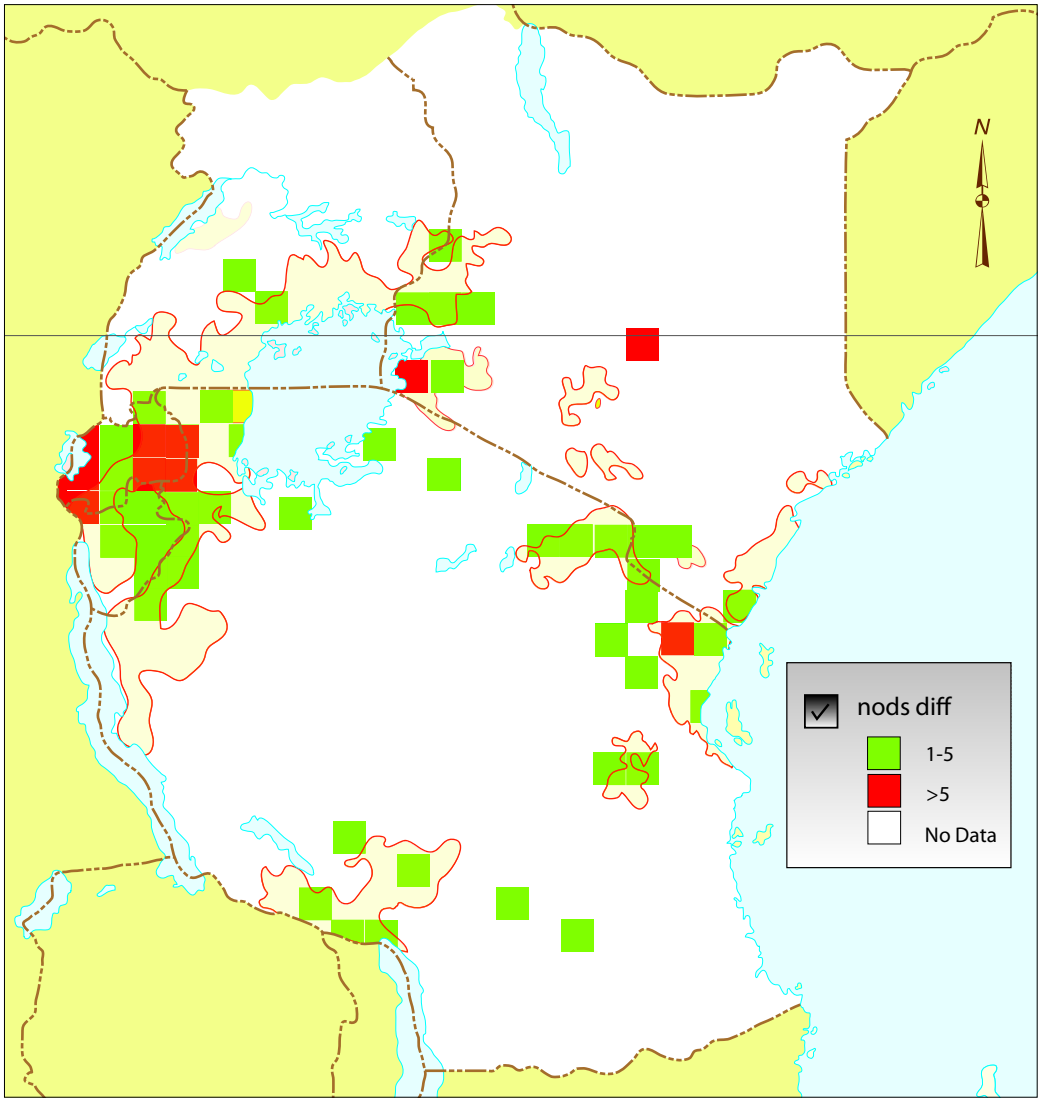


Fig. 8b. Number of observations for differences between farmer-named and distinct cultivars.



Number of observations

Ideally the number of observations should be the same for farmer-named and distinct cultivars. Figure 8b. details areas where differences exist between areas where several farmer-named cultivars could not be classed into distinct classes and/or were misclassified.

Number of different classes (cultivars)

Number of different classes of farmer named cultivars is shown in Figure 8c; Differences between classes of farmer named cultivars and the number of different classes of distinct cultivars grids/cells and where this phenomenon is high is detailed in Figure 8d. Differences of between –6 and 41 occur, as a result of synonym and/or homonym problems. A large number of cultivars (diversity) exist in areas consistent with those previously identified as cultivar collections (observations). (Between 1 and 127 cultivars exist in a single grid/cell.)

Figure 8c: Number of different classes of farmer-named cultivars

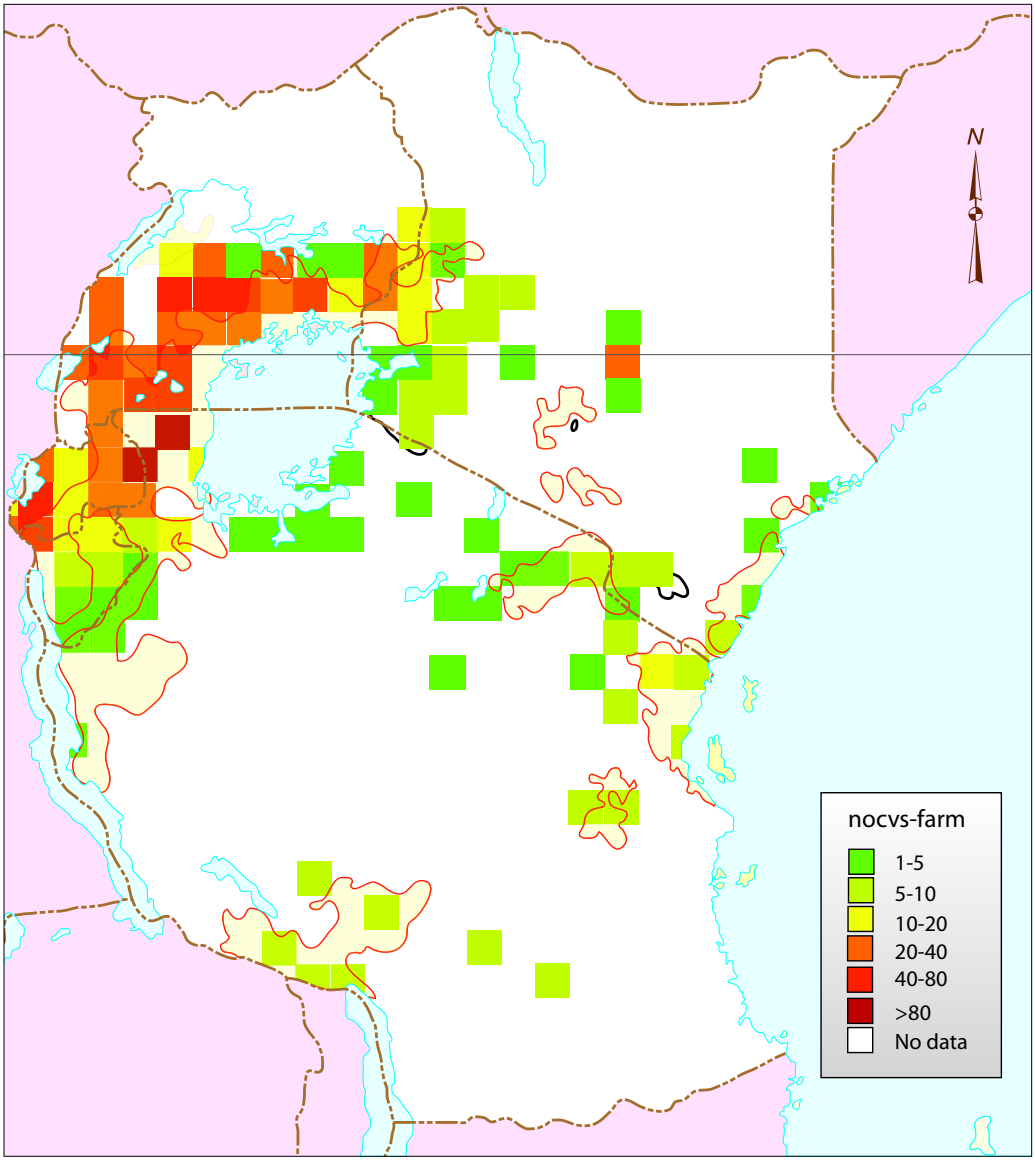
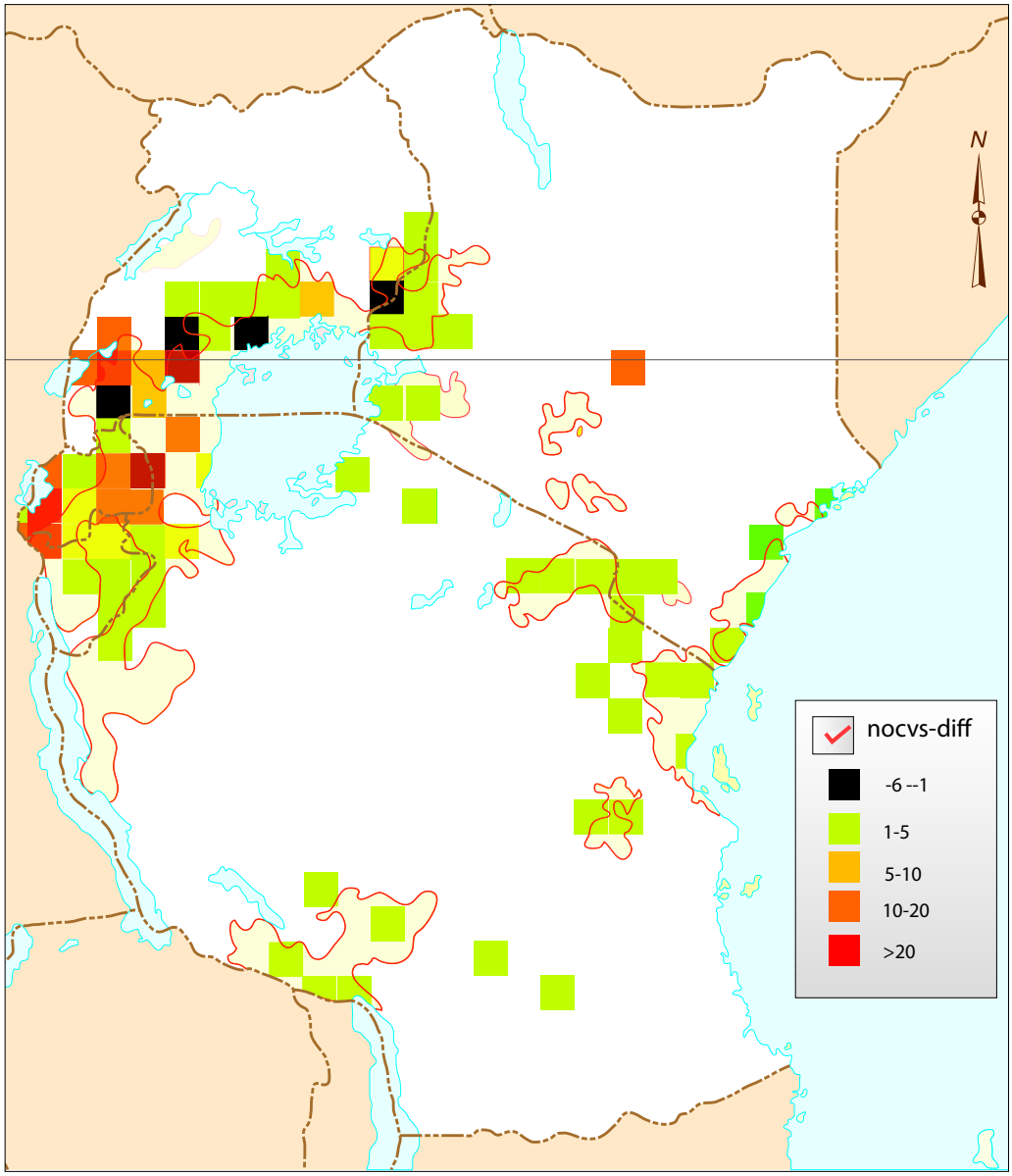


Figure 8d: Number of different classes of distinct cultivars compared to number of different classes of farmer-named cultivars



Diversity indices

These are mathematical measures of diversity which provide more information about community composition than simply richness. Unlike in the richness measure, relative abundance is taken into account and can also be used to provide information about rarity and commonness. The commonly used diversity index

is the Shannon diversity index (*H'*). (Begon, 1996, Hijimans et.al., 2002, Ludwig, 1988, Rosenzweig, 1995).

Shannon diversity index $H' = -? \, p_i \ln p_i$

where p_i – proportional abundance of the *i*th class = n_i/N

N – Number of observations per grid/cell

Figure 8e: Shannon diversity index (farmer-named cultivars)

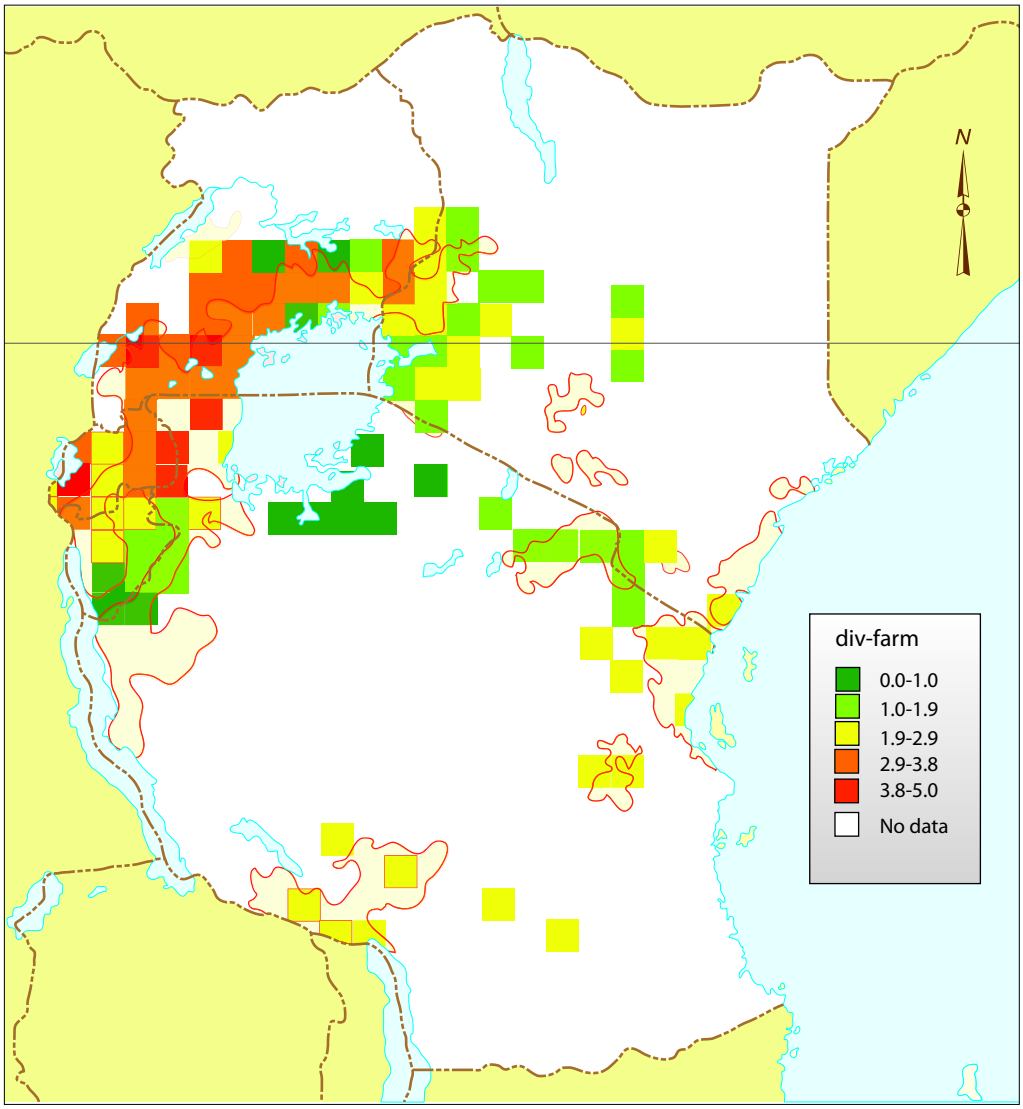


Figure 8f: Shannon diversity index: difference between farmer-named and distinct cultivar names

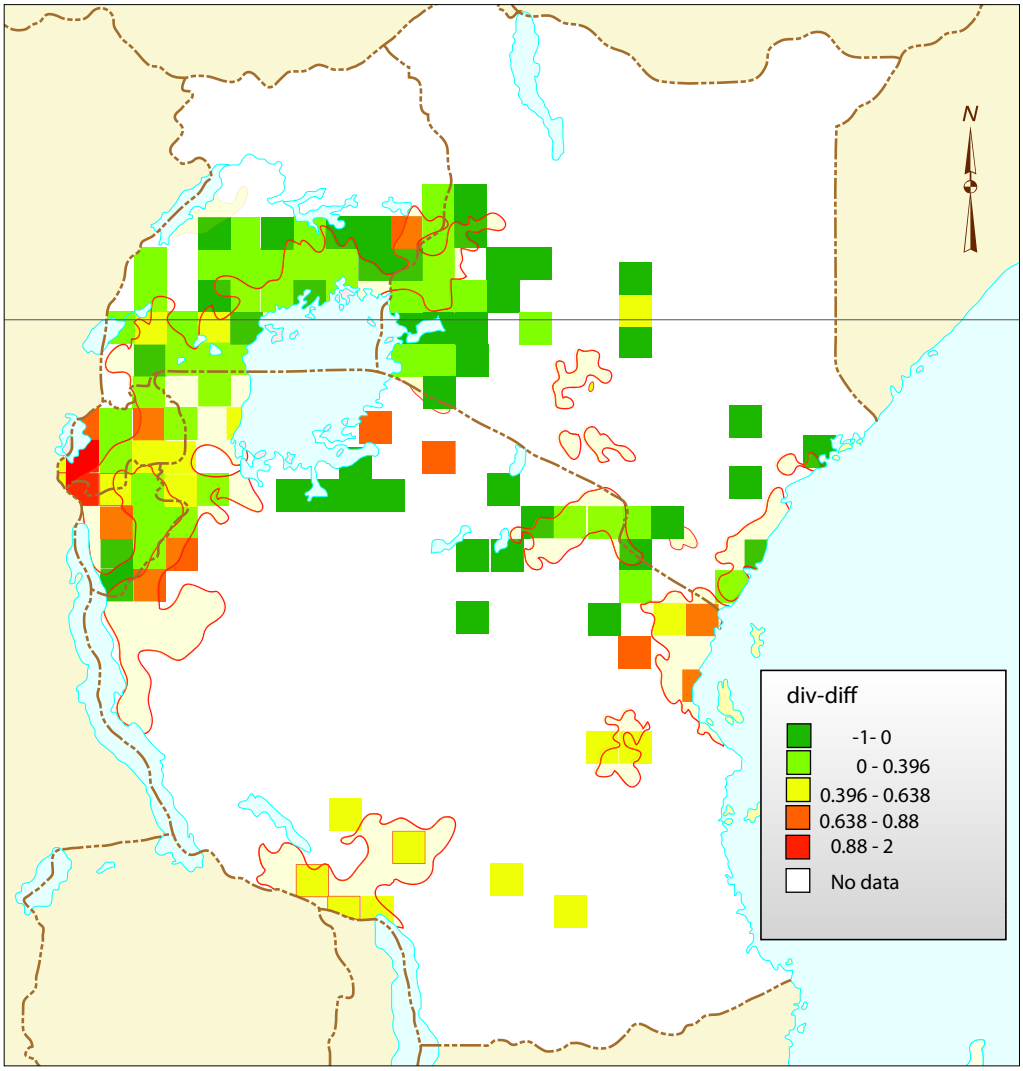


Fig. 8g. Complimentary grids/cells that capture maximum amount of diversity could indicate priority as far as In its conservation

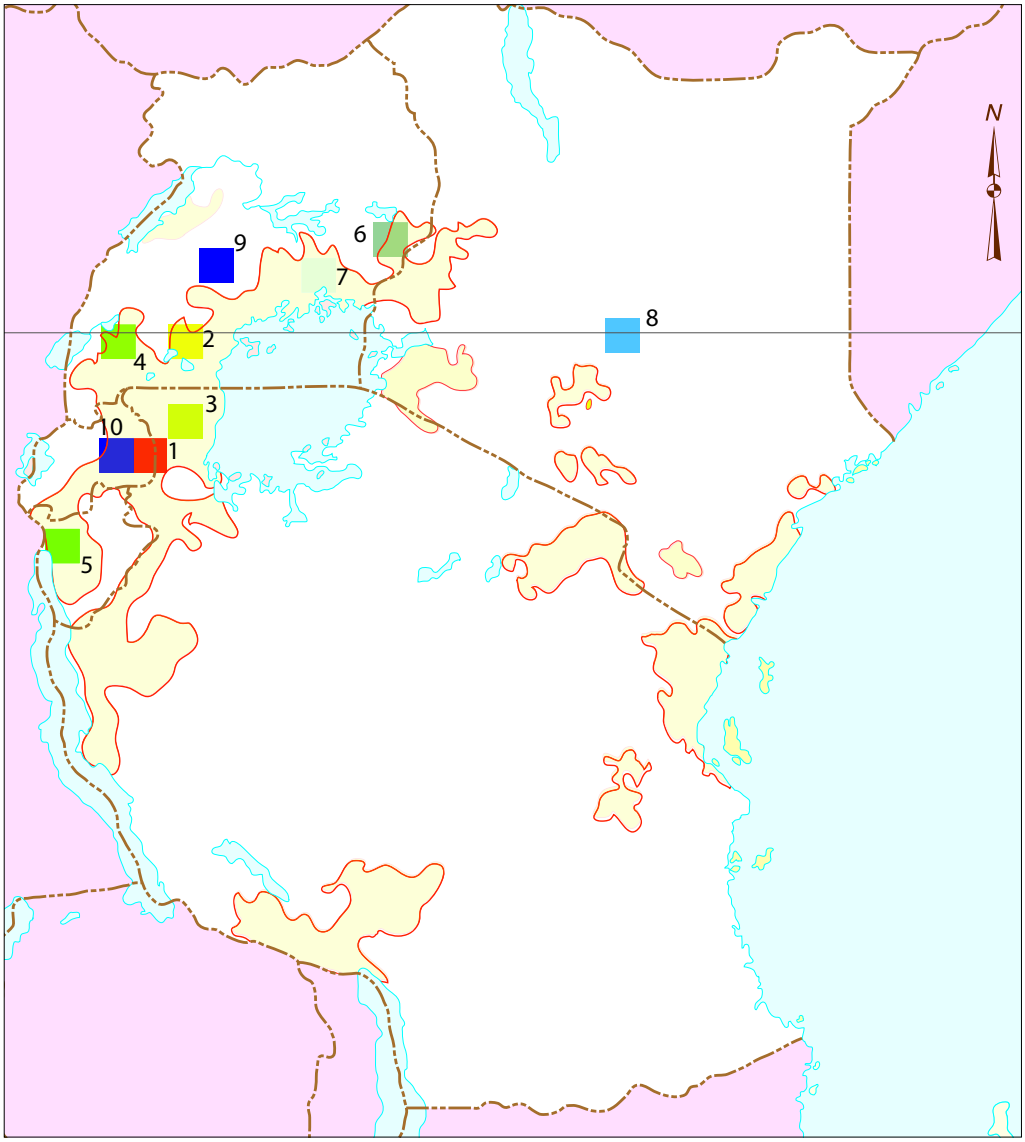
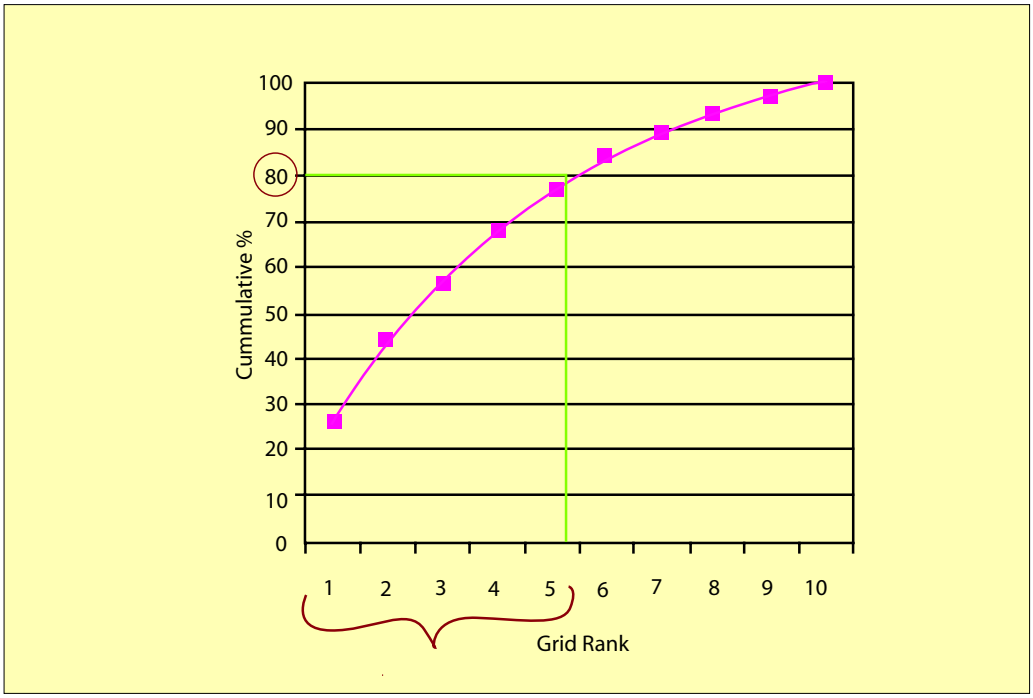


Fig. 8h. Diversity contribution by grids/cells



Areas of highest diversity are shown in Figure 8e, locations of hotspots of diversity are similar (compare with Figure 8c), albeit with diversity levels not exactly the same for the respective grids/cells. However, like in the richness (as number of different classes) case, diversity based on farmer-named cultivars is over-estimated in over 60% (63.6) of the cases with very few (2.5%) cases of under-estimation, which confirms a more widespread synonym (maroon-red grid/cells, Figure 8f.) problem.

Besides pinpointing hotspots for banana cultivar diversity, it is also possible to map out grid/cells or areas where most of the diversity can be captured. These are important areas if decisions are to be made regarding selecting priority areas for *in-situ* conservation. Richness complementarity analysis identifies sets of grid cells that are complementary to each other or grid cells that capture a maximum amount of diversity in as few cells as possible (approximate optimum solution). Based on the existing data, figure 8g details how much diversity is held within this grids/cells and this is shown in Figure 8h. All the diversity in the region is held within these ten grids/cells, with 80% within grid cells 1 – 5. This includes Kagera region in northern Tanzania; Kibungo and Lake Kivu areas of Rwanda and western parts of L. Victoria crescent (Rakai-Masaka-Sembabule intersection/boundary confluence) and northern Bushenyi and surrounding areas in Uganda.

The number of cultivars or other objects for that matter, observed in an area depends to some extent on the effort invested in recording information in that area. At the lower collections/observation rates, cultivar occurrence compares/correlates well with number of observations for the most part (Figure 8i). In the case of Shannon diversity index, a more stable measure of diversity is obtained after an optimum number of observations have been made (Figure 8j). Some approaches (estimators of richness), not explored here, are proposed to estimate the number of different classes that would have been observed if effort (as number of observations) had been equal for all cells. At the current mapping scale and level of data aggregation, eight observations per grid cell on average (range of observations is 1 – 156 where data exists) may be insufficient to capture reasonably the existing banana cultivar diversity in bulk of the area. All in all, for un-biased measure of richness/diversity, a minimum number of observations - depending on mapping scale (grid/cell size) - are necessary. Where there is need to expand cultivar inventory activities, a good protocol including minimum sample size, which can capture the local variability, is required.

Figure 8i: Relationship between number of distinct classes and number of observations

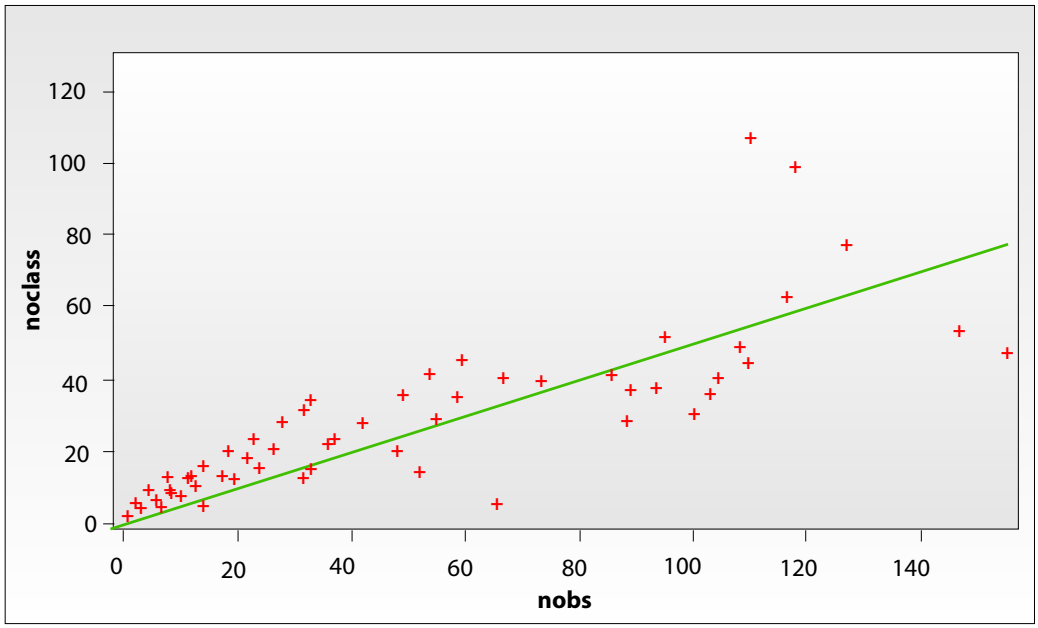
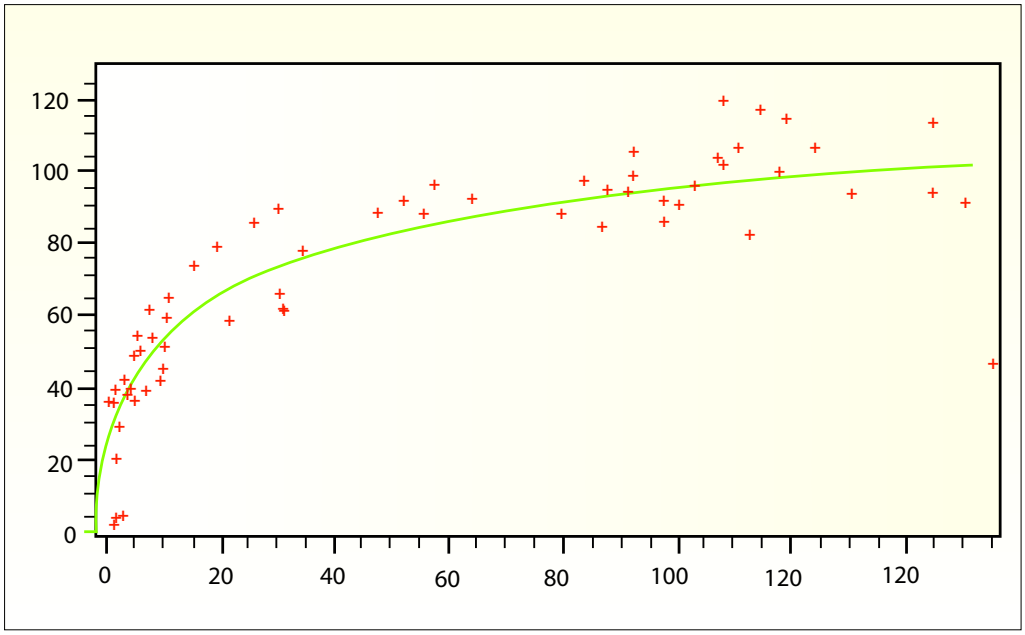


Figure 8j: Cultivar diversity versus number of observations



Conclusion

Application of spatial tools to banana collections data allows better visualisation of cultivar diversity information. Hotspots for diversity are mapped and can be related with other spatial data for further analysis. However, synonym and homonym problems can cause, to a large extent, exaggeration of the status of existing diversity. A suitable naming protocol is required in order to be able to present actual/reasonable diversity. Areas where diversity is misrepresented due to synonym and homonym problems can be mapped for further investigations. Those requiring additional collections, at the specified scale, are easy to identify, making it possible to target areas for additional collection missions. A certain minimum number of observations per grid/cell are necessary for meaningful results. With accurate data, spatial tools offer a good opportunity to map and describe banana cultivar diversity. The analyses can be used to guide collection/conservation missions.

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9

Morphological and molecular methods for the classification of bananas and plantains (*Musa* spp.)

Pillay Michael and Karamura Deborah

Introduction

The genus *Musa* L. (banana and plantain) is divided into five sections - *Eumusa, Rhodochlamys, Australimusa, Callimusa* and *Ingentimusa* (Cheesman, 1947-1950). *Eumusa,* the largest section, comprises the majority of cultivated and wild bananas. These were all derived from two fertile species, *M. acuminata* (AA) Colla and *M. balbisiana* (BB) Colla that were the contributors of the A and B genomes, respectively. *Musa acuminata* is not a single species but is rather a species complex that is divided into nine subspecies *viz*: *banksii, burmannica, burmannicoides, errans, malaccensis, microcarpa, simea, truncata* and *zebrina* (De Langhe and Devreux, 1960; Shepherd, 1988; Tezenas du Montcel, 1988). No subspecies have been designated for *M. balbisiana* as yet, but there is a wide range of genetic variation within the species as evidenced by morphological (Sotto and Rabara, 2000) and molecular (Ude *et al*., 2002a, 2002b) data. The wide genetic variation found in both the wild and cultivated bananas is the result of natural inter-specific and inter- and intra-subspecific crosses, vegetative multiplication, the long domestication process, human migration and genomic abnormalities (Perrier, 1993). Somatic mutations have also played an important role in generating this variability. Extensive intersectional crosses have also blurred the boundaries between some of the sections. The wide morphological variability in bananas and plantains, especially at the infra-specific level, has complicated their classification into natural taxonomic units.

Classification of bananas and plantains

While there is general agreement on the higher order classification of bananas and plantains, classification at the infra-specific level still remains problematical. The problem arises from the rules of the International Code of Nomenclature of

Cultivated Plants (ICNCP) that stipulates that taxonomic categories below the level of genus for crop species are restricted to cultivar group and cultivar (Trehane *et al*., 1995). These two categories do not cover the extent of variation present in cultivated plants such as bananas. Therefore a number of informal categories have been introduced to cover the variation between cultivar groups and cultivars (Pickersgill and Karamura, 1999). Simmonds and Shepherd (1955) and Stover and Simmonds (1987) introduced genome groups into *Musa* classification.The major genome groups in cultivated bananas include AA, AB, AAA, AAB, ABB, AABB and AAAB.

Further subdivisions of *Musa* into subgroups and clones was accomplished by De Langhe and Valmayor, 1980; Swennen and Vuylsteke, 1987; Swennen, 1988, and Lebot *et al*., 1994). Subgroups are named after the best-known clone in the subgroup ('Gros Michel', 'Bluggoe'), the cultivars first used to identify the main characteristics of the subgroup (Lugugira-Mutika, Maia Maoli-Popoulu) or a generic term (Cavendish and Plantain subgroups) (Jones, 2000). A detailed list of genome groups and subgroups in *Musa* is available in Jones (2000). The plantains were further divided into French and Horn (Simmonds, 1966) and the Horn subdivided into three categories as French Horn, False Horn and Horn types. Currently, there is general acceptance of genome groups and subgroups in *Musa* but there is no clarity on categories at the subgroup level and below. Karamura (1998) introduced the term clone set to group similar clones of East African highland bananas (AAA genome group, Lujugira-Mutika subgroup). A clone set is regarded as a taxonomic category above the clone but below the subgroup. On this basis, cultivars of the plantain subgroup can be placed into four main clone sets- 'French', 'Horn', 'French Horn' and 'False horn'. Clone sets are considered to have a predictive element in them, a factor that has been advantageous in most natural classifications (Karamura, 1998).

Morphological taxonomy

The current banana classification is based on the shape, color and appearance of different organs (Cheesman, 1947-1950; Simmonds and Shepherd, 1955; Simmonds, 1962). One of the primary reasons for using morphology is that numerous characters are available, no special technical means are required to observe them and it is cost effective. A large number of morphological descriptors are available to describe and classify bananas into groups (IPGR-INIBAP/CIRAD, 1996). These descriptors are divided into major and minor types. Morphological characters are generally coded as binary or as series of discrete states. Characters

could be qualitative (water sap versus milky sap) or quantitative (petiole length/ width ratio). Although morphology has formed the basis of classification for plants, it is influenced by genotype x environment effects and should, therefore, be used with caution. Morphological descriptors are often difficult to score especially when the character displays a very wide range in variation. For example, bract color shows extreme variation in banana. In a study of the Cavendish subgroup, Daniells (1990) found that the large number of variants and effects of environmental influences resulted in a continuum of variation for many characteristics. This made identification of individual clones extremely difficult. While many systematic studies continue to use morphology, the new trend in systematic studies is the use of molecular data, especially DNA, to classify plants and to compare morphological and molecular taxonomies.

Molecular taxonomy

Today, a wide range of molecular marker systems is being used to characterize plants at the molecular level. These include isozymes, restriction fragment length polymorphism (RFLP), random amplified polymorphic DNA (RAPD), amplified polymorphic DNA (AFLP), microsatellites or simple sequence repeats (SSR), expressed sequence tags (ESTs), DNA sequencing and SNPs (single nucleotide polymorphisms). In this paper a description of some of the most widely used methods in *Musa* are described. The interested reader will also find more information on this subject in Jarret and Gawel (1990), and Pillay et. al., 2012.

Proteins: Isozymes

Isozymes are different molecular forms of a single enzyme (Gottlieb, 1971). They have identical enzymatic properties but slightly different amino acid compositions that affect their migration in a matrix. Different techniques can be used to separate isozymes, including starch gel electropohoresis, polyacrylamide gel electrophoresis, iso-electric focusing and two-dimensional gel electrophoresis. In this way, isozymes become separated according to their size, charge and structure. When different molecular forms of an enzyme are separated on gels, the enzyme activity of the isozymes can be visualized by appropriate staining techniques. A banding pattern is produced. Isozymes have not been widely used in *Musa,* although it appears that they may be useful for species, subspecies and clonal identification (Jarret and Litz, 1986). Many enzyme-coding loci have been characterized in *Musa* (Jarret, 1987a, b). In a study using isozymes in *Musa*, Bonner

et al., (1974) were able to genotypically classify three clones of unknown origin demonstrating the potential of isozymes to differentiate banana cultivars.

Polymerase chain reaction (PCR)

PCR is a technique that uses a pair of primers, usually 15-20 oligonucleotides long, to amplify a specific region of the genome. A typical PCR consists of three basic steps. (i) DNA is denatured by heating to 90- 96° C bringing about separation of the double strands, (ii) annealing or cooling in which the two primers bind to the DNA, (iii) amplification or synthesis of the DNA is brought about by a DNA polymerase. Synthesis continues until each newly produced strand has proceeded far enough to contain the site recognized by the other primer. In this way, two DNA molecules identical to the original molecule are synthesized. Any PCR mixture contains a PCR buffer, dNTP mixture made up of the four nucleotides, a primer, Taq DNA polymerase, DNA template and sterile water. There is an exponential growth of the specific target fragments through successive cycles of amplification in a thermal cycler. The fragments are visualized after separation on agarose or polyacrylamide gels and staining with DNA binding dyes.

Restriction fragment length polymorphism (RFLP) markers

Restriction fragment length polymorphism (RFLP) is a technique in which plants may be distinguished by examining their DNA banding profiles after digesting the DNA with a restriction endonuclease. Basically, a RFLP is a band in a gel or in a Southern blot derived from a gel. Restriction endonucleases are enzymes that can digest DNA molecules at specific nucleotide sequences. When the nucleotide sequences at the cleavage sites between individuals are different the enzyme will cleave the DNA of one sample and leave the other uncut. Separation of these fragments by agarose gel electrophoresis would produce fragments of different sizes. The differences in fragment sizes are called restriction fragment length polymorphisms. RFLPs can be used to differentiate plants by examining differences in the DNA banding patterns. Therefore restriction fragments are separated by agarose gel electrophoresis, transferred to a nylon membrane according to the Southern technique and hybridized with a probe that identifies a specific DNA fragment. The probes are labeled with a radioisotope or chemically modified nucleotides and following hybridization the fragments are visible on an X-ray sheet.

For small genomes such as those found in chloroplasts and mitochondria, RFLPs can be visualized directly on a gel since it is possible to separate all the DNA fragments on a single gel. The disadvantage of RFLP markers is they are labour intensive, time consuming and require large amounts of DNA. It is possible to amplify specific regions of a genome using PCR and then digesting the amplified product with a restriction enzyme to obtain RFLPs. For example, Nwakanma *et al*., (2003b) used PCR-RFLP of the internal transcribed spacer regions of the ribosomal RNA genes to identify markers for the A and B genomes in *Musa*. Similarly, PCR-RFLP of organelle DNA sequences was used to construct a molecular phylogeny of *Musa* (Nwakanma *et al*., 2003a).

Random amplified polymorphic DNA (RAPD)

Random amplified polymorphic DNA (RAPD) is a PCR based reaction in which random segments of the genome are amplified by using short 10 basepair (bp) single primers (Williams *et al*., 1990; Welsh and McClelland, 1990). The amplification products are analyzed by electrophoresis in an agarose gel followed by staining with ethidium bromide. RAPD markers can also be converted to SCAR (sequenced characterized amplified region). In this technique, RAPD fragments are sequenced and specific primers of about 20-22 bp in length are synthesized. These longer primers are more reliable than the shorter 10 bp primers since they bind reliably to a region of interest in the genome. The RAPD technique uses very small amounts of DNA, a single primer is used for amplification and no prior knowledge of the genome is necessary for using this technique on any plant species. Primers are commercially available and are relatively cheap. Consequently, RAPD markers have been used extensively in several plant species. RAPD reactions are affected by the same variables that influence PCR reactions but the quality of DNA and the reagents are very important. RAPD analyses have been used widely in *Musa* for analysis of genetic diversity in diverse germplasm and genome identification. RAPD markers linked to A and B genome sequences were described by Pillay *et al*., (2000). Markers for the B genome were able to distinguish cultivars with a single B genome such as AB and AAB from those with two B genomes such as BB and ABB. Howell *et al*., (1994) identified RAPD markers that were specific to nine genotypes of *Musa* representing AA, AAA, AAB, ABB and BB genomes. Two modifications of the RAPD technique include DNA amplification fingerprinting (DAF) and arbitrary primed polymerase chain reaction (AP-PCR). DAF makes use of short random primers of 5-8 bp and produces a greater number of amplified fragments that are visualized by polyacrylamide gel electrophoresis and silver

staining (Caetano-Anolles *et al*., 1991). AP-PCR uses slightly longer primers, the amplified fragments are radioactively labelled and resolved by polyacrylamide gel electrophoresis (Welsh and McClelland, 1990). Kaemmer *et al*., (1992) used DAF and AP-PCR to detect genetic polymorphisms in a range of *Musa* genotypes.

Microsatellites and Variable number of tandem repeats (SSR and VNTR)

Most plants have simple DNA sequences that are repeated few to many times in the genome. The short repeated sequences of 1-6 bp are termed microsatellites or SSR (single sequence repeats) while motifs of 10-50 bp are called minisatellites or variable number of tandem repeats (VNTR). Length variations are very common in SSR regions. This variation can be detected with PCR by using primers that bind to the conserved DNA regions on either side of the SSR. SSRs are highly polymorphic even between closely related individuals. They are reported to be more variable than RFLPs and RAPDs. While SSR markers are quick to analyze and reliable, designing primers for the conserved regions requires DNA sequencing and this makes the technique costly and time consuming.

Inter-Retrotransposon Amplified Polymorphism (IRAP)

IRAP is a complementary dominant marker system used to detect polymorphism in retro-transposon insertions. The major classes of retroelements include long interspersed elements (LINES), short interspersed elements (SINES), copia and gypsy-like elements and retroviruses. Further details about this marker is found in Pillay et al. (2012).

Amplified fragment length polymorphism (AFLP)

Amplified polymorphic length polymorphism (AFLP) is a polymerase chain reaction based on fingerprinting technique that detects differences in DNA restriction fragments (Zabeau and Vos, 1993; Vos *et al*., 1995). The AFLP technique is complex and made up of the several steps. (i). The DNA is digested with two restriction enzymes, preferable a 4-base and 6-base cutter, (ii) double stranded DNA adapters are ligated to the ends of the restrictions fragments, (iii) a subset of the fragments are amplified by using two primers that are complementary to the adapters and the restriction site sequences, (iv) the amplified products are then separated on denaturing polyacrylamide gels. The fragments are made visible by means of autoradiography, silver staining or other methods. A typical

AFLP fingerprinting gel contains 50 to 100 amplified fragments and has high polymorphic information content. When compared to RAPDs, RFLPs or SSRs, the AFLP technique is better with regards to reproducibility, resolution and time efficiency. The single greatest advantage of the AFLP technique is the sensitivity to detect polymorphism at the total genomic level. AFLP makes use of stringent PCR conditions. The AFLP primers are generally 17-21 nucleotides long, and anneal perfectly to the target sites. This makes it a very reliable and robust technique which is unaffected by small variations in amplification parameters such as thermal cycles, template concentration, and PCR cycle profile. AFLP requires no prior sequence information of the DNA for the organism being studied. Polymorphisms detected by the AFLP technique are due to single nucleotide changes, deletions, insertions and rearrangements. The only disadvantage of the AFLP technique is that it is a long and tedious process that involves preparation of sequencing gels, using radioisotopes or silver staining. However, the total number of polymorphisms obtained from AFLP compensates for these disadvantages.

Diversity Arrays Technology (DArT)

DArT is a DNA hybridization-based genotyping technology, which enables low-cost whole-genome profiling of crops without prior sequence information. DArT reduces the complexity of a representative sample (such as pooled DNA representing the diversity of Musa) using the principle that the genomic 'representation' contains two types of fragments: constant fragments, found in any 'representation' prepared from a DNA sample from an individual belonging to a given cultivar or species, and variable (polymorphic) fragments called molecular markers, only found in some but not all of the 'representations' (www.diversityarray.com). DArT markers are biallelic and may be dominant (present or absent) or codominant (2 doses vs. 1 dose or absent). This approach enables quick profiling of segregating populations for quantitative trait loci (QTL) analysis with hundreds of polymorphic markers. Sequenced DArT markers can also be cheaply and rapidly anchored into BAC contigs, and therefore can facilitate the construction of high quality physical maps of the banana genome, which is a critical step in a sequencing project.

Single Nucleotide Polymorphisms (SNPs)

On average, SNPs will occur in an organism's DNA more than 1% of the time (www.biotech.iastate.edu). Most SNPs are found outside the regions of genes of interest because about 3-5% of an organism's DNA codes for proteins (Sherry et al. 2001). SNPs found in a gene of interest are of particular interest to researchers

because they are directly associated with a desired trait. Because of the recent advances in technology, SNPs are playing a greater role in selection and analysis of genetic traits.

Ecotilling

Till et al. (2010) has applied ecotilling for discovering polymorphisms in the Musa genome. They provide the following account of ecotilling, which is a high-throughput method for the discovery and characterization of SNPs and small insertions/deletions (indels) (Till et al. 2010). It is an adaptation of the enzymatic mismatch cleavage and fluorescence detection methods originally developed for the targeting induced local lesions in genomes (TILLING) reverse-genetic strategy (Colbert et al. 2001; Comai et al. 2004). It is an accurate, low-cost and high-throughput method for the discovery and evaluation of nucleotide diversity and has been used in many organisms.

Morphological versus Molecular classification in *Musa*

Modern methods using DNA techniques, by and large, seem to support morphological classification systems and at the same time provide new insights into the classification of bananas. The concept of genome groups in bananas is well supported by morphological (Perrier, 1993) and molecular data (Ude *et al*., 2002a; 2002b; 2003). In a two factor plot analysis of 155 cultivated and wild bananas using 71 morphological descriptors, Perrier (1993) showed that genomic groups in *Musa* were well defined. The AA diploids and AAA triploids accessions formed a group with a certain amount of overlapping. The ABB triploids formed two groups representing the 'Bluggoe' and 'Pisang awak' subgroups. The AAB bananas grouped closely with the 'Pisang awak' (ABB) subgroup. The plantains (AAB) were shown to be distinctly separate from the rest of the cultivars. The morphological classification of Perrier (1993) is in agreement with the molecular study that included some of these cultivars (Ude *et al*., 2002a). The latter study showed unequivocally that the genomic groups in *Musa* were distinct. The overlap between the AA diploids and AAA triploids accessions observed in the morphological classification was also apparent when DNA was used to classify the plants. The ABB cultivars, 'Bluggoe' and 'Fougamou', were grouped as a single group. Both the morphological and molecular data separated the plantains from the rest of the genome groups. The delimitation of sections in *Musa* has been defined on the basis of morphological characters, geographical distribution and hybridization studies (Simmonds, 1966; Argent, 1976). Molecular data showed that *Rhodochlamys* is indeed distinct from the other sections but closely related to the *M.*

acuminata complex (Ude *et al*., 2002a; Wang *et al*., 2002). Both morphological and molecular data showed that *Australimusa* and *Callimusa* are closely related (Ude *et al*., 2002a, Wang *et al*., 2002; Nwakanma *et al*., 2003a). Simmonds and Weatherup (1990) recognized the wide variability in *Eumusa* and divided the section into two informal groups- *Eumusa*-1 and *Eumusa* 2 on the basis of morphology. Organelle DNA polymorphisms also showed that there is a wide range of variation within the *Eumusa* (Nwakanma *et al*., 2003a). This is another example where DNA data supports the morphological data. On the contrary, molecular data can also be used to differentiate different cultivars. For example, the West African plantains 'Baka' and 'Ovang' share a similar morphology and were regarded as synonyms (Swennen and Vuylsteke, 1987). However, their DNA data showed that the two cultivars are very different with a genetic distance of 52 % between them. This underscores the importance of using both morphological and molecular data in taxonomy.

Future prospects

This paper has highlighted some of the molecular techniques used to fingerprint and identify bananas and plantains. The utility of DNA based markers in *Musa* for fingerprinting depended on the available technology at a particular moment. In the early 1980s, the most common available marker for assaying polymorphisms in the DNA was RFLP. The RFLP technique was superseded by amplification methodologies after the invention of PCR. RAPDs and its various modifications were widely used because they produce many markers without prior knowledge of the genome sequence. SSR markers were initially described in humans (Litt and Luty, 1989) and their potential for use in plants was soon recognized. In the early 1990s, the AFLP technique enabled the analysis of a large number of polymorphic restriction fragments. Recently new techniques such as single nucleotide polymorphisms (SNPs) are becoming more popular for germplasm fingerprinting. However, a prerequisite for identifying SNPs is the availability of DNA sequence data. There has been a surge in the available DNA sequences in many databases and it is possible to identify SNPs by 'database mining' (Chiapparino et al., 2004). Currently the high cost of identifiying SNPs is preventing its widespread use for fingerprinting. New simple and economical methods are being developed to exploit the potential of this technique. New DNA techniques are being invented on a continual basis for fingerprinting and genetic diversity studies in plants. It will be the onus of *Musa* researchers to exploit these techniques for the species.

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10

Options on the infra-specific classification of bananas in East Africa

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Introduction

The Infra-specific classification of both wild and cultivated plants has long been a complicated issue for a number of reasons; the major one being that variation at the infra-specific level is multidimensional and no longer hierarchical. Crops grow in simple communities and the conditions of growth around them are manipulated by man. Thus the variation patterns that exists among crops are not natural like those in wild plants i.e. products of these processes are not analogous to Darwinian evolution (a process giving rise to hierarchical relationship of character states to taxa). In addition, cultivated plants show large amounts of variation as noted by Parker, (1978), which is very difficult to handle at the cultivar level, while at the same time provide a type of classification that should be created to contain this information. Against the above in mind, many cultivated plant taxonomists have argued that the classification of cultivated plants should have the following considerations: ease and reliability of determining the status of names; ease and reliability of determining the application of names and user friendly, that is, driven by those who grow, sell, consume or otherwise utilize the plants concerned (Pickergill and Karamura, 1999; Jeffrey, 1968a). Since various crops have been domesticated in different directions, various authors as cited by Brandenburg (1986) argue that, specifically designed classifications were needed for complex cultivated plants in order to handle their variation properly.

Reflections on the evolution of bananas

Bananas have originated through a combination of interspecific hybridization, polyploidy and somatic mutation. Morphological and molecular evidence indicate that both cultivated diploids and the various groups of polyploid bananas have had multiple origins (Horry and Jay, 1990). Although sexual reproduction

does not occur anymore in cultivated bananas, somatic mutants have occurred independently in different progenitor clones. The various sorts of bananas (dessert, cooking and beer bananas) have spread through out the tropics for years. These have further diversified in different continents to which they have been introduced and have acquired names in local languages(Karamura and Karamura, 1994). The origin and diversification of bananas as described, has caused their classification to be difficult. Hybridization leads to reticulate rather than hierarchical relationships and may hide differences between previously distinct entities. Vegetative reproduction has led to small but consistent and persistent differences between lineages which may or may not be desirable to be recognized taxonomically (Pickersgill, 1996). Phenotypic plasticity has also caused differences which exceed those attributable to differences in genotypes. Also, inadequate sampling has caused variants, which were supposed to be part of the continuum, look very distinct because the intermediates which connected them are not known. Because of some of these reasons, the most widely used classification of bananas is both phenetic and phylogenitic and without rigidly sticking to one. However, biosystematics concerned with reconstructing the evolutionary history of crops or breeders wishing to exploit genetic diversity may want a phylogenetic classification which reflects pathways of evolution within the crop. Such classification should provide maximum predictive value about the distribution of characters not used in compiling the classification. Until recently, phylogenetic classifications of both wild and cultivated plants were subjectively inferred rather than objectively established. The objectively based phenetic or natural classifications are preferred since they enable the production of similar units which can eventually be fitted into a hierarchical classification. Besides, a phylogenetic classification of bananas is unlikely to be possible at an infraspesific level because hybridization has led to repeated merging of previously separated lineages. In view of the problems associated with the infraspecific classification of cultivated plants, Hanelt (1986) stated that classifications of cultivated plants should aim at surveying the variability, arrange the variability in determined units and interpret the relationships of these units.

Considerations on the classification of bananas

In bananas the existing informal type of classification of cultivars is that of Simmonds and his collaborators (Simmonds and Shepherd, 1955; Stover and Simmonds, 1987). Simmonds (1962, 1966) suggested that the formal Latin nomenclature should be abandoned and be replaced by the genome nomenclature

in which the cultivar is referred to by the genus and its appropriate group, e.g., *Musa* (AAA Group) 'Gross Michel'. This kind of treatment is permissible under the code of nomenclature for cultivated plants. In subsequent publications, Simmonds (1959) and Stover and Simmonds (1987) treated the genome groups as cultivar groups; whereby the classification of bananas in East Africa would have AA, AAA, AB, AAB, ABB. The category 'group' in this case is used to designate genomic groups. These genome groups are well established among the banana scientists. The classification however needs to interpret the relationship of the groups because for example, although the East African highland bananas belong to the AAA genome, they are distinctly different from the dessert or sweet bananas that have similar genomes (AAA). Below the level of group, banana scientists have established clusters of clones but not in any uniform basis. Subgroups are used to differentiate the clusters within the groups, for example Plantain, Pome and Silk are subgroup clusters within the AAB and Cavendish subgroup in genome group AAA. In the Cavendish subgroup, the clusters are mainly phenetic e.g. Dwarf Cavendish or Giant Cavendish (Daniells, 1990). In other subgroups somatic mutants arising from the same progenitor cultivar are included with it in the same family of related cultivars e.g. Green Red and Red. These families are phylogenetic. This indicates that multiple origins may not necessarily undermine the validity of hierarchical levels.

In bananas as in other clonally propagated perennial plants, the delimitation of the 'atomic unit' is much less clear than it is in annual crops (Pickersgill, 1996). For example is Dwarf Cavendish which has originated repeatedly from different members of the Cavendish subgroup a cultivar or does it represent an informal category equivalent to French or Horn plantains. The informal category 'landrace' is often used for field populations which are too heterogeneous to be recognized as cultivars but the heterogeneity in Dwarf Cavendish is between regions rather than within a given field population. The informal classification used by banana scientists employ up to three categories above the 'atomic unit'. There is one more rank needed at least for variable subgroups such as plantains and the Lujugira-Mutika clusters indicated by the morphological studies to accommodate taxa such as the French or Horn plantains which are below the rank of subgroup but above the rank of cultivar. No such categories have been provided by the code of cultivated plants. The code for Cultivated Code (Trehane et al., 1995) provides one category, cultivar group above the rank of a cultivar to treat the variation above the level of cultivar.

A morphometric study of the Lujugira-Mutika subgroup (EAHB) has classified the subgroup into five clusters (termed as clone sets) which conform to a considerable extent with local farming practices and also show some predictive value for scientists working on the crop. Clones studied in the farmers fields could also be assigned to these five clone sets. Molecular studies have supported further the existence of the four of the clone sets but not the beer clone set (Tugume, 2002 Buwa, 2009), an indication that the beer clone set may have arisen repeatedly from cooking bananas. However, the East African Highland bananas represent just a small portion of the spectrum of variation among the cultivated bananas in *Musa* section *Musa* (Karamura, 1999).

Pickersgill and Karamura (1999) debated that the category of cultivar- group in bananas could have been used at any one of the levels of subgroups or to the level of other clusters below subgroups. This was because the usage of genome groups as corresponding in rank to cultivar-group would not conform to Article 19 of the code of cultivated plants (Trehane et. al.1995). The article specifies that a cultivar-group epithet must be a word or phrase. It may therefore be preferable to use cultivar- group at the level of Simmonds' (1959) subgroups like Cavendish subgroup, the Lujugira-Mutika subgroup or Plantain subgroup. The genome group then becomes a useful informal category above cultivar-group. In their discussions, Pickersgill et. al. (1999) proposed a hierarchy of four ranks: genome group, cultivar group, clone set and cultivar.

A Taxonomic Advisory Group (TAG) which commenced in 2006 with a workshop in Cameroon in West Africa brought together banana taxonomists, molecular scientists, curators and breeders, who now provide guidance and technical support for clarifying issues of nomenclature and developing strategies for rationalising conservation efforts of Musa. TAG proposed a term 'cluster' to describe the different groupings within the different subgroups although the term did not get a full consensus, since no other alternative term was suggested. A cluster was considered to represent something genetically founded and should encompass the varieties that share common stable characteristics. For example 12 clusters had been proposed based on 4 bunch types with 3 sizes in each bunch category to describe the variation existing in the African plantains:

French Giant
French Medium
French Small

French Horn Giant

French Horn Medium
French Horn Small

False Horn Giant
False Horn Medium
False Horn Small
Horn Giant
Horn Medium
Horn Small

A space was provided in the Musa Germplasm Information System (MGIS) to enter the conclusions of any genetic or epigenetic studies related to these "clusters". MGIS is a unified information system (data base) which brings together information on the bananas held in collections worldwide, helping users to identify and source the exact kinds of banana they need for their particular purposes. In a similar manner, TAG suggested to add in MGIS the following clusters, 'Musakala, Nakabululu, Nakitembe and Nfuuka'belonging to the East African high land bananas.

Recommendation from the workshop

In the workshop of banana curators in East Africa, which was held in Kampala in 2004, (IPGRI/INIBAP Report, 2004) it was suggested that any infra-specific classification of bananas proposed by scientists, should not add more confusion which already exists. For the East African highland bananas, the workshop proposed to stick to four categories which best described the variation that existed in this subgroup and these were genome group, sub-group, clone set and clones. The clone sets would be Musakala, Nakabululu, Nakitembe and Nfuuka. Since Mbidde (Beer clone set) was not quite identifiable with the molecular studies, it was left out. With the variation of plantains that existed in East Africa, French, French horn, False horn and Horn could work as clone sets for plantains. The name of the cultivar could then be written *Musa* AAB-Plantains 'Horn' cv. Mamba or *Musa* AAA-EAHB Lujugira-Mutika 'Nakabululu' cv. Kibuzi. In this same workshop, it was proposed that the regional forum in the workshop should be named ECABACOS (The East and Central African Banana Conservation Society) and should be responsible for the following;

- To support the conservation of banana and plantains in East and Central Africa
- Facilitate the standardization of banana cultivar names

- Facilitate the exchange of information technologies among banana stakeholders,
- Support research and training on banana taxonomy and conservation
- Facilitate the description of banana/plantain in East and Central Africa,
- Maintain a register of all cultivars in the region and periodically update it and to enhance the utilization of banana diversity in East and Central Africa.

A task force was constituted with 8 members to be responsible for organizing the ECABACOS into a functioning society with all the administrative and management structures in place (IPGRI/INIBAP Report, 2004). It was this society which would link up to other organizations like TAG to assist in standardization of names as well as facilitating in the improvement of banana identification and classification

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An illustrated guide to the major clones of the East African Highland bananas in the great lake region

Annex 1a: Major clones of Mbidde clone set (Ref. Table 2a)



Endembezi (Indemera)



Engumba (Ingumba)



Ensika (Inshika)



Entundu (Intuntu)



Kabula (Enyamaizi)



Kyamalindi (Intembe)



Luwuuna (Igihuni)



Nalukira, Inkira (Enyarukira)

Annex 1b: Major clones of Musakala clone set (Ref: Table 2b)



Kisansa (Injagi)



Mukazi-alanda (Mushaija Nalanda)



Musakala (Barabeshya)



Muvubo (Mujuba, Enjubo)



Mpologoma



Namunwe



Enyoya (Inyoya)

Annex 1c: Major clones of Nakabululu clone set. (Ref. Table 2c)



Butobe (Intobe, Entobe)



Kattabunyonyi (Enyitabunyonyi)



Kibuzi, Kayuku (intermediate clone)



Mukubakkonde (Inyabutembe)



Nakabululu (Ingenge, Icyerwa- ntoya)



Nakyetengu (Nyakitengwa) (intermediate clone)



Entama , Intama (intermediate clone)



Salalugazi (Intermediate clone)

Annex 1d: Major clones of Nakitembe clone set (Ref: Table 2c)



Luwuuna (Igihuni, Oruhuuna)



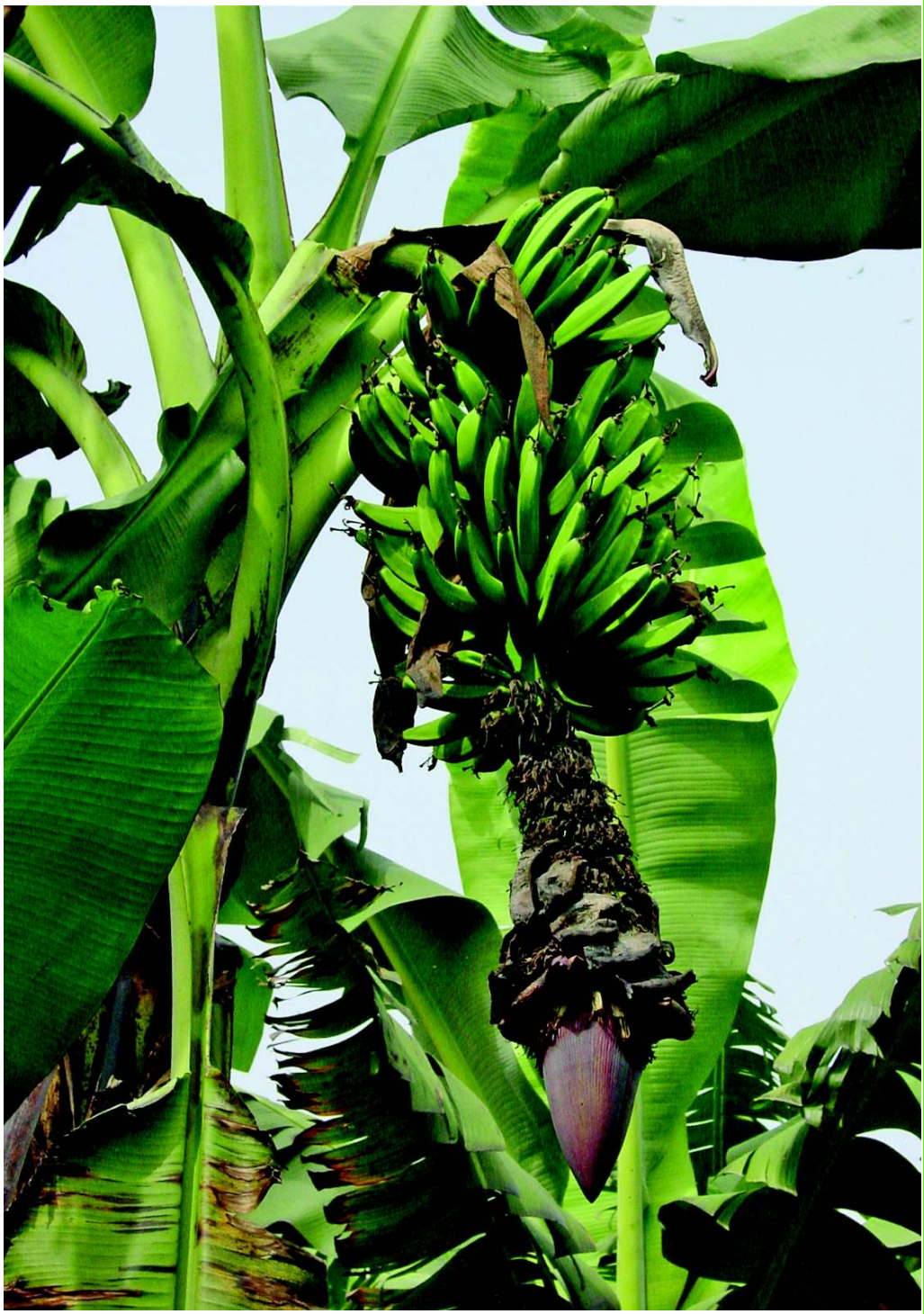
Mbwazirume (Mbwaziruma)



Nakitembe (Nyakitembe, Entaragaza)



Namaliga (Kirayenda)



Nandigobe (Ingagara)

Annex 1e. : Major clones of Nfuuka Clone set (Ref: Table 2e)



Bitambi (Naironi)



Bukumo (Inyabupfunsi)



Katwalo (Injogo, Empigi)



Kibalawo (Inzirabahima)



Nabusa, Inconnu (Enyeru, Endeishya)



Ndyabalangira (Inzirabushera)



Nfuuka (Ngaju)



Siira (Nsira)

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