Journal of Animal & Plant Sciences, 2009. Vol. 4, Issue 2: 341 - 356.
Publication date: 15 September 2009, http://www.biosciences.elewa.org/JAPS; **ISSN 2071 - 7024**

Banana (*Musa* spp. Colla) cropping systems, production constraints and cultivar preferences in eastern Democratic Republic of Congo

♣Dowiya, N.B., Rweyemamu, C.L. and Maerere, A.P.

Department of Crop Science and Production, Faculty of Agriculture, Sokoine University of Agriculture, P.O. Box 3005, Chuo Kikuu, Morogoro, Tanzania,

♣*Corresponding author email: dowiya@yahoo.com; Co-authors rweyemamucornel@yahoo.com and maerere@yahoo.co.uk*

Key words
Banana, plantain, production factor, cultivars preference

1 SUMMARY

Banana and plantain (*Musa* spp.) are important crops in the Democratic Republic of Congo (DRC) for food security and household income. However, yield has been decreasing to an average of 4.6 tons/ha currently, and the factors leading to the decline have not been fully determined. In the present study a diagnostic survey was conducted in the South Kivu (SK) and North Kivu (NK) regions of the country to determine the existing banana production constraints. Soil was sampled for analysis from 240 fields (30 samples/site) from 8 sites. The results indicated that apart from one site (Maboya, NK), soil fertility is not a limiting factor for banana production in the area. Planting materials used by farmers are exclusively suckers from existing crops and there is no institution producing clean planting materials in the area. Tillage using hand hoes for the purpose of growing common bean causes destruction of banana roots leading to poor nutrient uptake which contribute to low yield (3kg/bunch). Weed control is done by hand using hoes. Inadequate weeding and inappropriate desuckering practices increases competition between plants, leading to production of small bunches. In order of importance, the most important criteria for cultivar selection were flavour/taste, juice quality, resistance to disease and bunch size. Diseases including black Sigatoka, Fusarium wilt, Xanthomonas wilt, bunchy top virus, nematodes and weevils were identified as among the main causes of cultivar disappearance in eastern DRC. Although farmers have generally little knowledge on banana plantation management, they have good understanding on value addition through beer brewing. Hence farmers allocate an average of 50% of banana fields to wine producing cultivars. Cultivars from subgroup like AAA-Cavendish, AAA-Gros Michel, AAA-Ibota, AB-Ney poovan, AAB-Kamaramasengi and ABB are well adopted for wine making. A total of twenty nine and thirty two banana accessions were found to be grown by farmers in SK and in NK, respectively. Based on similarity among these accessions using farmers' criteria two clusters were identified consisting of wine/beer banana, and a combination of cooking, roasting and dessert types. The good market demand for plantains have motivated farmers in North-Kivu to allocate the largest part of their farms (25%) to French plantain Nguma (AAB) while in South Kivu the largest area (64.5%) is allocated to Nshikazi (AAA-EAHB) for beer production. Farmers' mixed cropping system includes legumes, cereals, and multipurpose

trees in the banana plantation or as hedgerows. Banana production can be improved in the study area using participatory research and development approach where smallholder farmers could evaluate appropriate technology introduced in the form of research. The key intervention measures are introduction of improved varieties with high yield and/or resistant to disease and sensitization on integrated pest management which could contribute into food security and poverty reduction.

2 INTRODUCTION

Sectoral Gross Domestic Product (GDP) contributions in the Democratic Republic of Congo (DRC) include agriculture (55%), industry (11%) and services (34%) (CIA, 2009). Bananas (banana and plantain) constitute the second most important source of calories after cassava in eastern DRC. The consumption ranges from 136.9 to 173.9 kg/person/year (Ministry of Planning, 2005a). Most of the population in eastern DRC practices small scale agriculture with banana and plantains as the predominant crops. The banana crop is mainly used for food and as a cash crop. Banana plantations also contribute to environment conservation as the crop grows throughout the year. Banana products (Juice, Wine, bunches and fibers) are consumed and marketed locally and, as a result, income generated from the crop circulates at village level (Sebasigari, 1987; Jagwe *et al.*, 2008).

The majority of cultivated bananas are triploid varieties belonging to the Eumusa section of the genus *Musa*, family *Musaceae* (Tenkuano *et al.*, 2007). These varieties evolved from intra- and inter-specific crosses involving two diploid ancestor species, *M. acuminata* Colla (genome AA) and *M. balbisiana* Colla (genome BB), which originated from Malaysia and India, respectively (Stover & Simmonds, 1991; Lusty *et al.*, 2006). In DRC, there has been only little research on banana since 1960s due to lack of manpower after the departure of Belgians after independence. However, the resumption of banana research programme around 1986 concluded that bananas were produced on small scale in farms characterized by mixed banana varieties and intercropping, without any mechanization or renewal of plots for almost 30 years (Sebasigari, 1987). Unfortunately, there was no continuation of banana research due to insecurity in North Kivu and South Kivu regions after three years implementation. However, Bakelana and Makangidila (1996) evaluated the banana and plantain production throughout the country and reported low yields ranging from 4.6 to 4.9 tons/ha; they concluded that banana production is constrained by the following problems: Traditional cultural practices, field diseases and the lack of government funding for banana and plantain. The following diseases and pests, ranked according to the degree of severity (1=rare, 2=mild, 3= severe and 4=very severe) have been found on plantain and banana in Zaire: *Fusarium* wilt/Panama disease (3), Black and yellow Sigatoka (3), Virus disease/bunchy top (2), Banana weevil (4) and Nematodes (3). The Zaire government has funded several agricultural projects in the past but almost none on banana and plantain. This information remaining general for the whole country didn't give any information on a particular province such as North Kivu or South Kivu.

There is need for on-farm banana production study to determine the factors contributing to this low yield especially in eastern DRCongo. Therefore, the objective of this study was to determine the banana production constraints that hinder food security, farmers' cultivar preferences and the cropping systems practiced.

3 MATERIALS AND METHODS

A survey using an interview schedule was conducted in South-Kivu and North-Kivu provinces from 2nd to 29th March 2008**.** The province of South Kivu with an area of 69 130 Km² having 3.9 millions of population, is located at East of Democratic Republic of Congo (formerly Zaire) especially between 1° 36' - 5° latitude South and 26° 47' - 29° 20' longitude East (PNUD, 2009b). SK's population densities vary between 100 and 123 persons per km², the mean of annual rainfall is distributed between 1437 mm and 1661mm with a long growing season (365 days) and altitude of 950 to 2019 m above sea level (masl) (Farrow *et al.*, 2006). SK is bordered at East by the Republic of Rwanda through river Ruzizi and by Burundi and Tanzania through Lake Tanganyika, at South-East by Katanga province; at South, West and North-West by Maniema province and at North by NK province. SK is divided into 8 districts (territories) (Ministry of Planning, 2005b).

The province of North Kivu covering an area of 59 631 Km² and having 4.9 millions of population, is also located at East of Democratic Republic of Congo especially between 0°58' latitude North- 02° 03' latitude South and 27° 14'-29° 58' longitude East (PNUD, 2009a). NK's population densities vary between 59 and 122 persons per km², the mean of annual rainfall is also distributed between 1268 mm and 1556mm with a long growing season (365 days) and the altitude of 909 - 1803 masl (Farrow *et al.*, 2006) . NK is bordered at East by the Republic of Uganda, at South East by the Republic of Rwanda, at North and West by the Oriental province, at South-West and South by Maniena and SK provinces respectively. It is divided in 6 districts (territories) (Ministry of Planning, 2009a).

In each province two districts/territories were purposively selected and within each district two divisions (sites) were randomly picked from a participatory rural assessment (PRA), according to agro-ecological conditions, market accessibility and population density (Table 1) (Farrow *et al.*, 2006).

At each site, five sub-sites (Table 1) were selected. In each sub-site six farmers according to wealth categories: two rich (with at least 2 ha of banana and cattle (at least 25 cows), two average (with at least 1 ha of banana and livestock (at least 1-3 cows or 10 goats) and two poor (having a plot of bananas with at least 50 mats (<0.5 ha) and without livestock) were selected for interview. The interviewees in different categories were identified with the aid of village leaders, from which a sampling frame were prepared.

A total of 240 farmers were interviewed in the entire study. Interviews were conducted at each selected farm where farmers were to indicate their preferences for the different banana accessions (i.e. local cultivars) in term of fruit yield, taste, juice productivity and juice quality. Farmers' preference on banana cultivars was recorded in term of characters which guide their planting material's selection. They were asked to list the ten most productive cultivars in terms of taste, juice quality and the five best for juice production. The respondents were also asked to identify banana production constraints that they were facing.

Direct observation (transect walk) in each farm (by the researcher) was conducted after each interview in order to (1) Describe the cropping system; (2) Assess agronomic practices in place; (3) Verify cultivar preferences by determining the cultivars present within the fields. (4) Verify the listed banana production constraints.

Various methods described by Robinson (1996), Eckstein *et al.* (1995), Tenkuano *et al.* (2007) Blomme *et al.* (2008) and Dens *et al.* (2008) were used to identify and characterize banana production factors. Diseased banana samples were collected and analysed using methods described by GPC (2008) for infection and pest infestation.

Soil samples were collected at the depth of 20 cm in the banana field of two farmers per category per sub-site. These were analyzed for their physical and chemical proprieties in the laboratory of the Department of Soil Science at Sokoine University of Agriculture, based on methods described by Page (1982).

The product-moment correlation coefficient was used to assess similarity among banana accessions. A correlation matrix was calculated and cluster analysis carried out by the group average method using NT-SYS package according to Karamura (1999). Descriptive statistics and regression coefficients were computed using SPSS package, while ANOVA was done using the GenStat package.

Journal of Animal & Plant Sciences, 2009. Vol. 4, Issue 2: 341 - 356.
Publication date: 15 September 2009, http://www.biosciences.elewa.org/JAPS; **ISSN 2071 - 7024**

Table 1: Characteristics of Sites, population and Access to markets within time zones from PRA Sites in Sud-Kivu and North-Kivu Mountain

Location			**Access to market:**								**Agro eco. characters**		
South-Kivu		**Pop. dens.**	**Bukavu**		**Kigali**		**Kibuye**		**Cyangugu**		G[3]. days	A.rf[4] mm	E[5] m
Sites	**Sub sites**	**P/km²**	**H[1]**	**mi[2]**	**H**	**mi**	**H**	**mi**	**H**	**mi**			
Luhihi (Katana)	Cirhundu, Kabuguli, Mwirunga, Rubona, Luhihi	123	7	26	14	37	10	58	9	51	365	1497	1555
Kabamba	Ceyar I, Cifinjo, Kaboneke, Kahanga, Lukayu	100	2	7	9	9	5	29	4	45	365	1551	1594
Lurhala Centre	Buganda, Isimbu Bukalye, Karambi, Nalushose	128	6	17	14	37	10	57	9	2	365	1661	2019
Mwegerera (Burhale)	Cinyimba, Ishali, Kashozi, Nkanga Mbulamishi,	123	2	42	11	3	7	23	5	28	365	1554	1664
North-Kivu			**Kasindi**		**Butembo**		**Kampala**		**Beni**				
Munoli	Luseke, Munoli, Nguva, Vwasa Tamende,	59	14	0	8	23	28	15	8	36	365	1515	1760
Maboya	Kaliva, Masunga Vughano, Kitahuha, Vuvembe	59	11	23	5	20	25	37	5	58	365	1470	1403
Mutwanga	Kisanga, Taliha Kyavitumbi, Mapou, Nzenga,	122	1	23	4	18	15	49	4	27	365	1268	1048
Mangodomu	Mangodomu, Mulua, Kalibo, Kasopo, Somicar	122	3	33	3	20	17	48	3	0	365	1482	1010

Source: Farrow *et al*. (2006). [1]= hours, [2]= minutes, [3]= Growing season, [4]= Annual rainfall, [5]= Elevation

Journal of Animal & Plant Sciences, 2009. Vol. 4, Issue 2: 341 - 356.
Publication date: 15 September 2009, http://www.biosciences.elewa.org/JAPS; **ISSN 2071 - 7024**

4 RESULTS AND DISCUSSIONS

The results (Figure 1) reveal that there are more rich farmers in North Kivu (NK)(25.84%) then in South Kivu(SK) (8.33%) even there are more average farmers in NK (23.33%) then in SK (18.33%), but lesser poor farmers in NK (50%) then in SK (73.34%). The self decision of farmers to maintain their roads by manual labour since 1990's in NK could justify the facility of movement of banana from village (farms) to the nearest town (Butembo or Beni) and abroad (Kampala). Butembo is the farmers' town, built by them. The name Butembo come from the word "butembe" meaning "*Insete* spp." which is one of herbs at that site on Ndande ancestors' arrival in the area (Isale). The Ndande ancestor (Yira) consider that banana originate from *Insete* spp. Banana constitute their staple food. Farmers in SK don't have the self will of maintaining their roads by manual labour and their roads have disappeared completely, hence high difficult condition of banana trade (Table 1). The average banana field is small (0.7 ha per farmer). A possible explanation for this (small banana field) is that the study area is mountainous with undulating land that is laborious for banana cultivation through building contour line which most farmers are not aware of. Although more suitable land exists where the terrain is flat, the population is higher there and the land is used also for cattle grazing. The lack of sensitization on the appropriate technique of land use and family planning could be part of the raison.

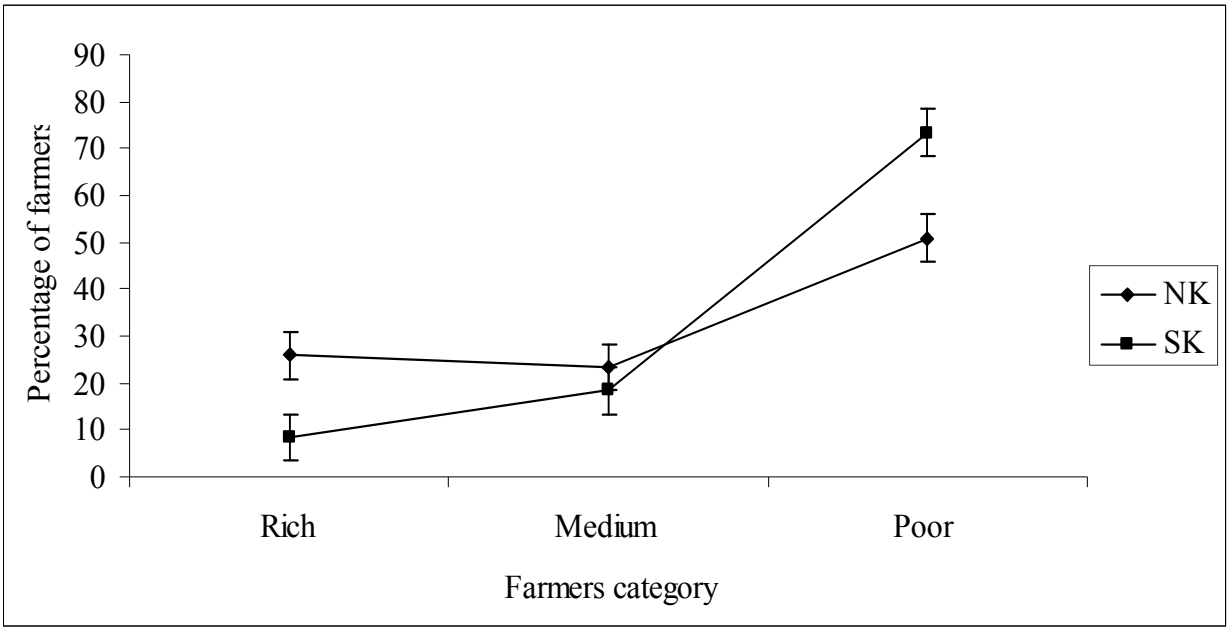


Figure 1: Proportion of farmers (%) as categorized based on wealth status in North Kivu and South Kivu provinces in the Democratic Republic of Congo**.**

The rich farmers "*Bashamuka"* who operate at commercial level own more than four hectares of banana (called *Lukoma* i.e., many hectares of banana in the Mashi dialect of South-Kivu) with less then 25 cows in SK (due to war) but with more then 50 cows in NK, with their children studying up to University; also the cattle farming supply manure used in the banana field. This result into production of big bunches of banana throughout the year which ensures self-sufficiency. The observed effect of manure use is similar to that documented by Michigan (2008) and that observed in respect to manure management by the Haya tribe of Tanzania (Yamaguchi & Araki, 2003).

Banana cultivars that produce small bunches and short fruits with yellow pulp (Nyaghenghe, Kagenge, Nyambururu, Kagera masisi, and Mbwene) or one hand horn plantains (Chibulanana or Kitsirambalavala, Kisambiko, and Sanza moya) were not preferred by poor farmers due to limited acreage. These results were supported by the finding of Karamura (1999) in the case of Ugandan farmers' preferences. However, the high bunch yielding, best tasting and juice quality local

cultivars were widely grown by all farmer categories. The lists of the ten most preferred cultivars per province are presented in the subsequent paragraphs (regression tables) combined with outcome of on farm verification.

The study shows that most of farmers in the study area (85%) are between 20 and 65 years old. The age of the respondents in South-Kivu province ranged from 24 to 90 years (Figure 1) with 44% of those interviewed being women. The proportion of women (44 %) in banana production in SK shows the level of their involvement in banana production systems in term of food security. This women proportion support the report of PNUD (2009b) which state that the household's proportion leaded by women in SK is less poor (66%) in term of food security compared to the proportion of poor house hold leaded by a men (87%). This explains the low implication of men in banana production which is mostly limited to brewery processing activity and management of it generated income without care of banana cultivation activity in SK. Hence, men sensitization on the weakness of traditional culture which reserve agriculture labour to women according to DSRP (2008) for their involvement in agriculture production constitute the way of poverty reduction in SK. On the other hand, in North-Kivu province, farmers' age ranged from 20 to 81 years with 16% being women. The men proportion (84%) involved in banana production activity are in line with the increase proportion of medium to rich farmer in NK. The results on the distribution of age show that banana farmers have long life expectance compare to other farmers having other crops (Cassava) as staple food. The oldest farmer in both locations was a man (aged 81 or 90 years) from the poor category; hence life expectation of banana farmers is above the total of life expectation such as presented by the National Statistic Service (DSRP, 2008). The development of three towns (Goma, Beni and Butembo) in NK province constitutes the indication of beginning of development due to men involvement in agricultural activity.

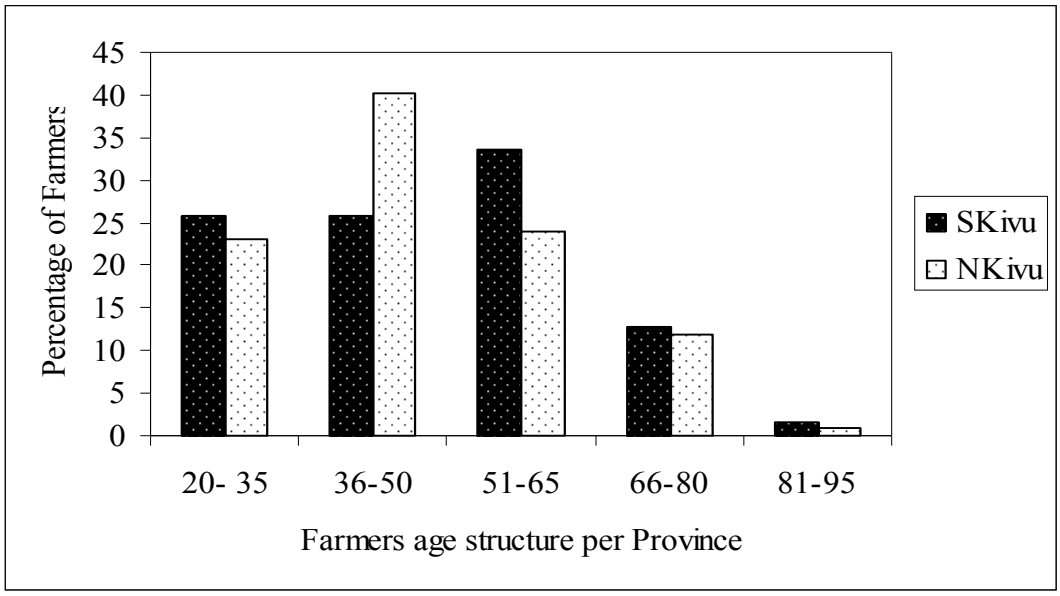


Figure 2: Age structure of farmers in South and North Kivu provinces in DR Congo.

Soils analysis results (Table 2) show that apart from Lurhala and Mutwanga, which are characterized by silt-clay and sandy-loam soil types respectively, all other sites have well drained clay soils. The pH in water (Table 2) in the study areas ranges from 5.1 to 6.5, which is medium acid and is within the optimum range for banana. The results show that except for Maboya site with the pH_{CaCl2} of bulk soil very acid (3.98), all other sites have acid (4.59) to medium (5.9) acid soils. There was no significant difference between pH in water or in bulk soil either between farmers of different categories or between sites at $P \leq 0.05$ levels. The cation exchange capacity (CEC) of the soils is medium ranging from 10.2 to 23me/100g. This shows that the clay minerals in eastern DRC are kaolinites. The organic matter (OM) concentration between 4.39 – 6.22 % is medium while the total nitrogen (N) of 0.41 to

0.58 % is high. The division of Katana/Luhihi, which is the most important source of East African Highland Banana (EAHB) in south Kivu, is characterized by soils with a pH of 6.2 in water and 5.8 in $CaCl_2$, which are within the optimum range for banana and is composed of well drained clay with medium chemical properties (Table 2). According to Pecrot (1958) this site is settled on recent volcanic soil. The site of Munoli, with soil properties similar to Luhihi (Table 1), is the main center of banana production specially the EAHB (cooking and beer banana) in North Kivu. This area, which includes Isale locality/sub division, has a century old banana plantation. The respondent with the age of 81 years mentioned that his banana plantation was an inheritance from his grand father. The Ndande tribe's ancestors called "Yira" settled at Isale with their first banana (Mukingiro, Nzirabahima). Mangodomu and Mutwanga sites, which constitute the main center of plantain production, are characterized by soil with medium to high nutrient content. This soil property is similar to those described by Delvaux (1995). Low yields (2.8-3kg/bunch) obtained by farmers at Maboya can partly be explained by the observed low soil fertility (Table 2).

Table 2: Physico-chemical properties of soils in eastern DR Congo.

Site	Soil type	pH_{H2O}	pH_{CaCl2}	CEC[1]	OM[2]	N[3]	P[4]	K[5]	Ca[6]	Mg[7]
South-Kivu										
Kabamba	clay	5.45	4.54	13.16	5.12	0.43	49.94b	0.52	3.92	2.48
Luhihi	clay	6.24	5.37	12.30	4.99	0.45	37.48c	1.44	6.93	3.63
Lurhala	silt-clay	5.61	4.59	12.56	5.13	0.49	18.87d	0.51	2.82	1.42
Burhale	clay	5.48	4.65	15.26	5.88	0.57	68.36a	0.77	3.09	1.62
North-Kivu										
Maboya	clay	5.10	3.98	10.20	4.72	0.58	48.89b	0.21	0.96	0.39
Mutwanga	sandy-loam	5.96	5.05	18.60	6.22	0.53	41.9bc	0.49	6.94	4.03
Munoli	clay	6.52	5.80	14.20	4.39	0.41	22.14d	1.77	7.76	4.51
Mangodomu	clay	6.51	5.90	23.00	6.18	0.52	78.89a	0.74	15.2	8.40
		Cv%:9.1 Lsd:1.7	Cv%: 13.7 Lsd: 2.18	Cv%: 23 Lsd: 10.92	Cv%: 11 Lsd: 2	Cv%:15 Lsd:0.24	Cv%:7.4 Lsd:10.7	Cv%: 81 Lsd: 2	Cv%: 41.9 Lsd: 14.82	Cv%: 81.2 Lsd: 8.55

Note: These values shown are mean of 6 samples per sub-site. [1] Cation exchange capacity (me/100g), [2] Organic matter (%), [3] Total Nitrogen (%), [4] Extractable phosphorus (mg/kg), [5] exchangeable Potassium (cmol/kg), [6] exchangeable Calcium (cmol/kg), [7] exchangeable Magnesium (cmol/kg).

The results show that there are 29 and 32 local cultivars grown by farmers in South Kivu (SK) and North Kivu (NK), respectively. It was established that the planting materials' origins is inheritance (40%) from parent and gifts from neighbours (60%, N=240). The Bashi tribe ancestors arrived in South Kivu with most of their highland banana such as the "Nshikazi" meaning "belonging to Bashi" (*Nshi* = tribe Bashi and *kazi* = belong to, dialect *Mashi*). Nshikazi (Shika) is also called "magizi", which means "bitter". The Bashi tribe got the plantains from the Barega tribe through dowry. Thus plantains are called "musheba" meaning "wedding" in Mashi dialect. In North Kivu, apart from the inherited cultivars such as Mukingiro, the cultivars Kitoke/Mathoke and Nyakitembe are from Uganda; while Nguma, Tuntu (Tundu), Nyaghenge are said to originate from South Kivu. The cultivar Kisubi mangango which is close to Yangambi km 5 in term of taste and growth habit and many other plantains is from the Congo forest basin.

Figure 3 shows that most farmers' land is allocated to beer banana types with 63.5 and 33.7 % (N=120) in SK and NK, respectively. The genomic groups (Figure 4 & 5) used in beer making are wide and include AAA-EA-beer (43-70%), AAA-ibota (7-12%), AAA-kamaramasengi (5-7%), AAA-cavendish (12-13%) and AB-Ney poovan (2-14%) and ABB-group (4-11%). The major beer banana cultivar in South Kivu is Nshikazi. On its own this cultivar covers an average of 42.9 % (Table 3) of all banana fields and contributes up to 52% (Figure 4)

Journal of Animal & Plant Sciences, 2009. Vol. 4, Issue 2: 341 - 356.
Publication date: 15 September 2009, http://www.biosciences.elewa.org/JAPS; **ISSN 2071 - 7024**

of raw materials for making beer. The increasing contribution (13%, Figure 5) of Cavendish group in beer making in eastern DRC indicates adoption and adaptation of this variety by small scale farmers. Farmers attributed the current situation in land allocation (Figure 3) to two reasons: the first is the fact that harvested bunches are processed into juice and beer which can be kept and sold over a longer time and generate more income compared to cooking and dessert banana which spoil after a short time because of market problems. Secondly, beer banana constitutes the traditional income reserve, which is released progressively. Apart from the similarity in land allocation to beer banana in eastern DRC, there is a different scenario for other banana types.

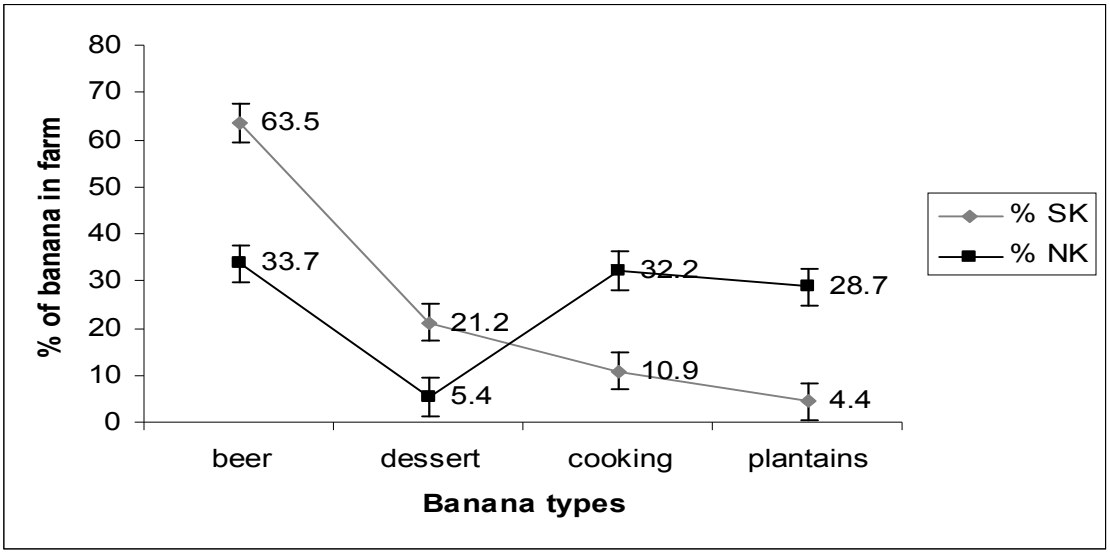
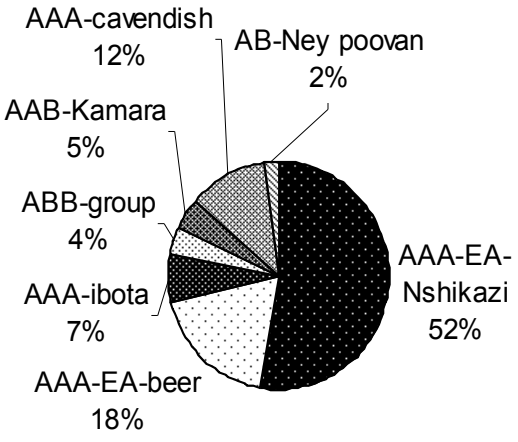


Figure 3: Types of banana grown in South Kivu (SK) and North Kivu (NK) provinces in eastern DR Congo.



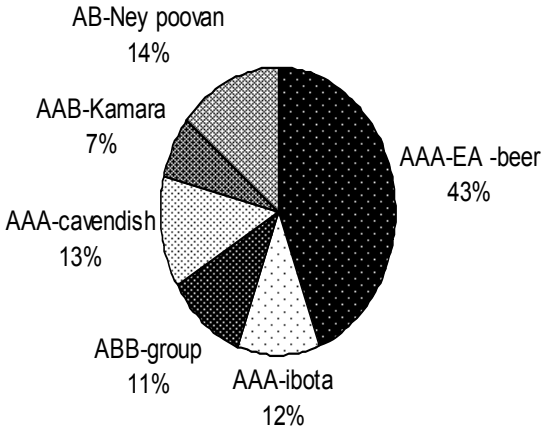


Figure 4 (left): Genomic groups of beer banana in South Kivu province**; Figure 5 (right):** Genomic groups of beer banana in North Kivu province, eastern DR Congo.

In South Kivu, high market demand for dessert banana has led to expansion of its production. The results (Figure 3) show that dessert bananas (21%) are second to beer banana (63.5%) in terms of land allocation, followed by cooking banana (10.9%) and plantains (4.4%), which are mostly grown for subsistence. In North Kivu, the high local market demand (in Butembo and Beni) for cooking types and the demand in Kampala, Uganda, for plantains

Journal of Animal & Plant Sciences, 2009. Vol. 4, Issue 2: 341 - 356.
Publication date: 15 September 2009, http://www.biosciences.elewa.org/JAPS; **ISSN 2071 - 7024**

have raised the allocation of these types to second (32.2%) and third (28.7%) positions, respectively.

The results show that the most productive cultivar is Nshikazi (AAA-EAHB-beer) in South Kivu and Nguma (AAB-French-plantain) in North Kivu provinces (Table 3). The tenth most productive cultivar is Cisukari red (green red) and Kalole II (AAB-Kamaramasengi) for south Kivu and North Kivu respectively.

Table 3: Regression between banana preference in term of bunch yield and land allocation

		X_1				Y		
N°	Most productive Cultivar	% respond. (N=120)	% in farm (N=120)	β	SE_β	Unstand.(b)	t-value	Signif.T
SKivu		**R^2 0.25**	**$R^2_{adju.}$0.24**	**F = 39.45**		**d.f (118)**	**Signif. p<0.001**	
1	Nshikazi[1]	64.5	42.9	0.501**	0.015	0.093	6.281	0.000
2	Barhabesha[2]	19	2	0.120	0.393	0.512	1.305	0.195
3	Kamelamasengi[3]	14.9	3.7	0.114	0.169	0.256	1.512	0.133
4	Kisamunyu[2] (Cinyamunyu)	14	4.1	-0.010	0.168	-0.017	-0.099	0.921
5	Gros Michel[3]	9.1	2	-0.105	0.214	-0.215	-1.005	0.317
6	Musheba[4]	8.3	2.2	0.242*	0.239	0.515	2.157	0.034
7	Malaya (Kitika)[3]	8.3	2.6	-0.041	0.233	-0.070	-0.299	0.766
8	Chindege[3]	3.3	5.3	0.038	0.246	0.056	0.229	0.820
9	Yangambi Km 5[1]	3.3	5.7	0.079	0.742	0.265	0.357	0.725
10	Chisukari/green red[3]	1.7	3.8	0.613	0.246	0.502	1.903	0.106
NKivu		**R^2 0.34**	**$R^2_{adju.}$0.29**	**F = 8.063**		**d.f (16)**	**Signif. p <0.025**	
1	Nguma[4]	25	9.4	0.080	0.370	0.310	0.838	0.404
2	Vulambya[1]	21.7	9.3	0.081	0.316	0.271	0.856	0.394
3	Tuntu[1] (Tundu)	17.5	8.3	-0.058	0.267	-0.152	-0.571	0.569
4	Kitika sukari kiri[3]	17.5	3.6	-0.137	0.423	-0.475	-1.123	0.265
5	Mukingiro[1]	12.5	6.5	-0.116	0.721	-0.499	-0.692	0.494
6	Kitoke(Mathoke)[2]	11.7	3.4	0.579*	0.910	2.584	2.839	0.012
7	Kisubi mangango[1]	8.3	4.1	-0.581	1.200	-1.914	-1.596	0.171
8	Kisubi musa[1]	7.5	3.8	-0.585	0.505	-0.630	-1.248	0.301
9	Mudjuva[2]	3.3	2.5	0.519	0.202	0.213	1.052	0.370
10	KaloleII[3] (Kamela)	2.5	2	-0.617	1.030	-1.143	-1.109	0.383
			Constant	*10.581* *1.028*		-	*10.228*	*0.000*

* Significant at 0.05 levels. ** Significant at 0.01 levels. [1] Beer type, [2] Cooking type, [3] Dessert, [4] Plantain

There was strong positive correlation (R = 0.501, N=120) for South Kivu and weak correlation (R= 0.34, N=120) for North Kivu between the proportion of cultivars on farm and the most productive cultivar. Thus allocation of large portion of farmers' field (Table 3) to the most productive banana cultivars in SK is explained by the high population density which needs food security, and the subsistence characters of this production. But the market demand in NK has influence the land

allocation such as farmers allocate their land to the most productive including the market needs. The market needs in NK has thus reduced the goodness of the determinant coefficient (R= 0.34).

The best cultivar in respect to taste/flavour was Kamelamasengi (AAB-Kamaramasengi) (Table 4) for South Kivu and Vulambya (AAA-EAHB-cooking) for North Kivu provinces. Of the ten ranked cultivars, the least preferred in terms of taste was Sukumba/Mugombozi (ABB-Bluggoe) and Kitoke/Mathoke (AAA-EAHB-cooking) in South Kivu and North Kivu, respectively.

Table 4: Regression between the best tasting banana and land allocation.

Prov/rank	Best taste Cultivar	X_1 %respond. (N=120)	β	SE_β	Y Unstandard(b)	t-value	Signif.T
S. Kivu	**R^2 0.044**	**$R^2_{adju.}$ 0.036**	**F = 5.424**		**d.f (118)**	**Signif. p <0.025**	
1	Kamelamasengi[3]	24.8	0.210*	0.267	0.621	2.329	0.022
2	Barhabesa[2]	16.5	0.042	0.024	0.011	0.458	0.648
3	Nshikazi[1]	12.4	0.154	0.045	0.074	1.652	0.101
4	Kisamunyu[2]	10.7	0.176	0.056	0.102	1.826	0.071
5	Gros Michel[3]	9.2	-0.097	0.053	-0.049	-0.927	0.356
6	Musheba[4]	7	0.205	0.038	0.068	1.774	0.080
7	Malaya[3]	6.6	0.102	0.145	0.106	0.729	0.469
8	Ndundu[1]	6.6	0.132	0.077	0.060	0.774	0.444
9	Cisukari[3] red	5.8	0.412	0.088	0.164	1.864	0.080
10	Sukumba[1]	3.3	0.417	0.371	0.417	1.123	0.304
N.Kivu	**R^2 0.112**	**$R^2_{adju.}$ 0.088**	**F = 4.645**		**d.f (37)**	**Signif. p <0.050**	
1	Vulambya[2]	40.8	-0.088	0.020	-0.018	-0.921	0.359
2	Pakuma[2]	25	-0.089	0.035	-0.031	-0.898	0.371
3	Nyaghenge[2]	11.7	0.103	0.048	0.041	0.845	0.401
4	Kalole[3]	10	0.334*	0.441	0.951	2.155	0.038
5	Musilongo[4]	10	-0.024	0.469	-0.042	-0.090	0.930
6	Nguma[4]	5.8	-0.850*	0.645	-2.179	-3.229	0.032
7	Kitikasukari kiriI[3]	4.2	-0.387	0.549	-0.800	-1.456	0.171
8	Nzirabahima co[2].	3.3	-0.014	0.291	-0.013	-0.045	0.965
9	MudjuvaI[2]	2.5	-0.939	0.467	-1.803	-3.859	0.061
10	Kitoke[2]	2.5	-0.741	0.284	-0.313	-1.102	0.469
		Constant	*8.791*	*2.116*	-	*4.154*	*0.000*

* Significant at 0.05 levels. [1] Beer type, [2] Cooking type, [3] Dessert type, [4] Plantain

A weak correlation (R = 0.210 for South Kivu and R = 0.334 for North Kivu) was observed between cultivar with best taste/flavour and its proportion (%) on farm. The little influence of land allocation to banana cultivar by the criteria of taste/flavour in both provinces is explain by the fact that some best tasted banana producing small bunch are not grown by poor farmers who constitute the majority of the population.

Regarding the production of juice and beer, farmers have classified the five best cultivars as shown in Table 5. The best cultivar for juice/beer production was Nshikazi (AAA-EAHB) with a score of 76% while Ndundu (AAA-EAHB) had the lowest score (4.1%) in south Kivu. In North Kivu the best cultivar with a score of 35% was Tundu (AAA-EAHB) followed in decreasing order to a score of 15% for Kitika sukari kiriI (AAA-Cavendish) (Table 5). A positive but weak correlation (R = 0.207, South Kivu and R = 0.101, North Kivu) was observed between the best cultivar for juice/beer production and its proportion on farm. The correlation results are in line with the observations of Richards (1985) cited by Engels *et al.* (1995) indicating that local farming practices are not a matter of traditions, but of active innovation and invention; in the case that farmers by their own experience have set criteria for banana's land allocation assuring their food security and increasing their income. This shows the fact that adoption of improved banana could be easy through the involvement of farmers in the on-farm selection

Journal of Animal & Plant Sciences, 2009. Vol. 4, Issue 2: 341 - 356.
Publication date: 15 September 2009, http://www.biosciences.elewa.org/JAPS; **ISSN 2071 - 7024**

process. In South Kivu, the most important criterion (Figure 6) used by farmers to select banana cultivars is the combination of flavour, taste, and juice production (FL, 86%); whereas in North Kivu the outbreak of Banana *Xanthomonas* wilt disease that is devastating most banana types has influenced farmers' criteria of selecting cultivars.

.

Table 5:: Regression between the best juice producing cultivar and land allocation.

Prov./ rank	Best juice cultivar	X_1 % respond. (N=120)	β	SE_β	Y Unstand.(b)	t-value Signif.T	
S Kivu	**R^2 0.043**	**$R^2_{adju.}$ 0.035**	**F = 5.308**		**d.f (118)**	**Signif. p <0.025**	
1	Nshikazi[1]	76	0.207*	0.039	0.089	2.304	0.023
2	Gros Michel[2]	9.1	-0.004	0.027	-0.001	-0.038	0.969
3	Malaya[2]	11.6	-0.092	0.055	-0.042	-0.758	0.451
4	Kamela masengi[1]	9.9	0.232	0.062	0.098	1.583	0.121
5	Ndundu[1]	4.1	0.144	0.518	0.346	0.667	0.512
N. Kivu	**R^2 0.010**	**$R^2_{adju.}$ 0.002**	**F = 1.175**		**d.f (114)**	**Not Signif. At 0.05**	
1	Tundu[1]	35	0.101	0.661	0.717	1.084	0.281
2	Mukingiro[1]	26.7	-0.011	0.952	-0.100	-0.105	0.917
3	Kisubi mangango[1]	21.7	-0.094	1.158	-0.877	-0.757	0.452
4	Katarina[1]	20	-0.170	1.162	-1.316	-1.133	0.264
5	Kitika sukari kiri[1,2]	15	-0.030	3.836	-0.310	-0.081	0.938
		Constant	*7.326*	*2.691*	-	*2.723*	*0.007*

* Significant at 0.05 levels. [1] Beer type, [2] Dessert,

Hence, farmers have generally adopted resistance to pest (RP, 65%) as the major criterion for selecting planting material in NK. After these major criteria, the other criteria in decreasing order of importance are bunch size (BU), the availability of planting material (AV), adaptation to poor soil fertility (RS), market demand/prices (MD), resistance to drought (RD), short production cycle (SC) and sustainable production (SP). Farmers argued that such factors/constraints are temporal, but food need to be sufficient first and appetizing for producer and consumer.

The phenogram (Figure 7) shows two clusters in respect to how farmers use banana. The first cluster of 23 cultivars (Kalole 2 (D1) to Cingulube (D53)) consists of beer making types, while the second cluster is subdivided into three sub-clusters. The first sub-cluster of 13 cultivars Kingulungulu (P3) to Cibulanana 1 (P61)) consists of roasting banana types; the second sub-cluster of 8 cultivars (Kitika kiri (D6) to Kitika kikuhi 1 (D21)) consists of dessert types while the third sub-cluster of 17 cultivars (Kiware (C8) to Isanzi (P54)) consists of soft cooking banana types. The correlation coefficients of similarity (Figure 7) have shown that the three main characters that contributed up to 87% in grouping banana cultivars in the two clusters were characters in respect to consumption, cooking ability and maturity. The genomic composition of the first cluster is wide as stated previously (Figure 4 & 5). Farmers' criteria of classification alone are not able to make differentiation between banana genome groups. For example the French plantain Musheba and Walungu 16 (horn) are fitted in the first sub-cluster (dessert banana), due to their fast maturing trait, bunch size and fruit sweetness when it is ripened. Farmers have started consuming raw when ripen some plantain, due to food insecurity created by population density and food scarcity. This information is useful for breeders during selection of cultivars for on-farm evaluation in eastern DR Congo.

Journal of Animal & Plant Sciences, 2009. Vol. 4, Issue 2: 341 - 356.
Publication date: 15 September 2009, http://www.biosciences.elewa.org/JAPS; **ISSN 2071 - 7024**

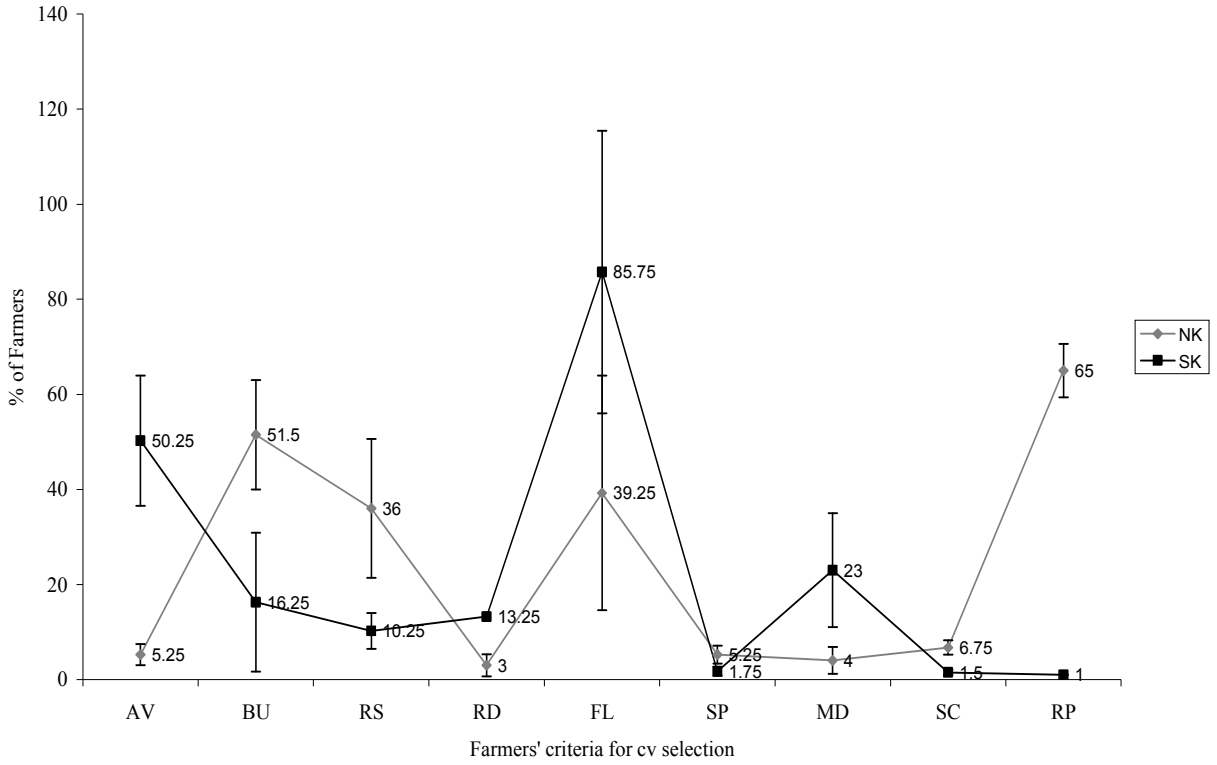


Figure 6: Farmers criteria for selecting planting banana's materials.

The results showed that the selection of banana planting materials is done during the wet season. The responsibility for selection is equally shared (50%) between men and women in South Kivu; while 90 % of cultivars selection is done by the head of household in North Kivu. In both provinces, about 84 % of planting materials are selected on the planting day and 16% 2 to 4 days before the planting day. It is noted that beer bananas is mostly selected by men because brewery activities and sale are performed by males. Women are involved in selecting cooking and other type of banana as they are the ones who cook and/or transport and sell them in the markets.

According to the symptoms described by Mak *et al.* (2007) and Molina (2007) Gros Michel, Kamela masengi and Kisubi have disappeared in some places from eastern DR Congo due to *Fusarium* wilt. From sample of diseased plants collected from the study area, different species of *Fusarium* have been isolated, such as *Fusarium c.f. oxysporum* (on AAA-Cavendish), *Gliocladium, Fusarium sacchari* and *Fusarium solani* (on AAA-EAHB, beer (Ndundu) and cooking (Barabesha) types). This new banana pathogen isolation show that according to farmers cropping system characterized by mixing banana with sugar cane (*Saccharum officinarum*), *Solanum nigrum*, *Solanum tuberosum* among other, Soil pathogen previously known having different crops as plants host have started infecting banana. Moreover, other diseases like banana bunchy top virus (BBTV) locally named "Sindika" as described by Robinson (1996) and nematode damage according to symptoms described by Chabrier *et al.* (2008); Munroe (2009) and Agri-Net (2009) were observed. From samples taken, various species of nematodes were isolated such as *Meloidogyne, Helicotylenchus multicinctus* and *Radopholus similis*. All other cultivars such as Ngorya, Cibirangondo, Musilongo, many types of Musheba, Pome, Buhake, Bumpavu, Kisubi, Lushuli, Masisi, Kiware, Mukingiro, Ngenge, Barhabesha, Ndundu and Isanzi may have disappeared due to weevil and nematodes damage. The most important diseases that have contributed to the disappearance of cultivars are BBTV, *Xanthomonas* wilt and Black Sigatoka. This is confirmed by the fact that De Langhe (1961) cited by Stover and Simmonds (1991) has collected about 56 cultivars in the region and planted in INERA-Mulungu station but now a

day there is only 32 cultivars remaining. This suggests a collecting mission in order to find out if they could be found in other area (somewhere else) of the provinces. Hence, germplasm conservation becomes an alternative for escaping cultivars disappearance in the region.

Survey results have shown that in eastern DRC, farmers use only suckers as planting material. They don't use tissue cultured plants or corm bits. As stated previously, the source of these suckers is from own existing banana field or from neighbours. There is no research institute or private sector producing clean banana planting material.

The agro forestry systems applied by farmers in banana systems both in South Kivu and North Kivu consists of scattered trees in plantation where most of the trees are *Persea americana*, *Carica papaya*, *Mangifera indica*, *Citrus sinensis, Psidium goyava, Citrus deliciosa* and *Citrus limon*. These trees are planted as sources of fruits. Moreover, they have multipurpose tree hedgerows like *Grevillea robusta*, *Accassia* sp., *Cassia siamea*, *Eucalyptus* sp., *Musanga* sp., *Cupressus* sp., and *Ficus* spp. These species are used for building and are also a source of income. The farmers also practice *alley* planting only when mixing banana with *Coffea arabica* or *Cinchona* sp.

Farmers also mix banana with *Phaseolus vulgaris, Arachis hypogea*, *Vigna unguiculata*, *Zea mays, Oryza sativa, Saccharum officinarum, Solanum nigrum,* and *Sorghum bicolor*. An inappropriate practice was observed whereby farmers till (land preparation) at around 25 cm deep in the banana field before sowing beans. Blomme et al. (2008) has determined that 45% of banana root system is in the zone around 25-30 cm deep, which mean that when farmers till banana fields, they destroy about 45% of the banana root system. Damage to roots reduces water and mineral uptake of the plant, and constitutes one of the reasons of low yield and small bunches (Robinson, 1996). The average weight of banana bunch from these fields was 3 kg/mat.

Farmers (60 %) with small fields do not practice fallowing while farmers with large fields practice fallowing in order to manage diseases and to restore soil fertility. About 92% of the interviewed farmers in eastern DRC practice desuckering. It was established that 55 % of farmers in South Kivu leave 3 to 6 suckers per mat, while in North Kivu 84 % of the farmers leave between 4 and 7 suckers per mat. Thus, a mean of 4 suckers is usually left per mat in eastern DRC after desuckering. Farmers' reasons for desuckering include that the practice minimises shade, allows intercropping and increases banana yields. The majority (73%) of farmers in South Kivu conduct desuckering all times during farm visit, whiles in North Kivu about 83% conduct desuckering during weeding. According to Robinson *et al.* (1996), Tenkuano *et al.* (2007) and Dens *et al.* (2008), the high number of suckers left per mat could be one of the reasons for low banana yield.

The method of detrashing (dry leave removal) seems to be known to 75% of farmers in eastern DRC, who apply it during weed control. The results show that most farmers (60%) are not aware of the importance of debudding (male bud removal) which is a recommended practice to improve uniformity of fingers and reduce infection by *Xanthomonas* wilt and cigar end rot. A few of the farmers who are aware explained that debudding increases finger and bunch size. During farm visits, it was observed that even those farmers who are aware of the importance of debudding do not do it on their farms.

About 72% of farmers practice propping in order to prevent breakages of pseudostems due to wind. Propping is conducted during bunch development when the need arises. Cultivars propped are all that produce big bunches and/or have tall stems. Amongst cultivars propped are Barhabesha, Gros Michel, Kamela masengi, Nshikazi, Malaya, Nakasimbu or Buganda (Yangambi km 5), Cindege, Musheba, Kashulye, Nsha, Bulengere, Cingulube, Poyo and Chibulanana in SK; and Tuntu, Mukingiro, Vulambya, Kitika sukari kiri I, Nguma I, Kiware I, Kitika sukari kikuhi2, Kitoke, kithavwira, Kalole, Vuhindi and Mudjuva I in North Kivu.

After harvesting banana, farmers split and spread the pseudostems in the fields. For them, this practice increases soil fertility and reduces soil erosion. In both SK and NK farmers weed using hand hoes only. About 80% of the farmers are weeding 2 to 3 times per year, while 13% weed 4 times per year and 7% weeding 5 to 12 times per year. Rich farmers are those who are weeding several times (7-12 times /year) for having the required bunch for the market. On the other hand, the small bunches (mean of 2.8 kg/bunch from mixed weed with banana) seen in poor farmers and some medium farmers' field can partly be explained by the low weeding frequency (2 to 3 times per year) practiced, while the rain fall through the year

(365 days) in the study area allow high growth of weed which create high competition with banana root system reducing hence banana root up take of soil nutrient. This result of small bunch due to low weeding frequency is in line with the finding of Robinson *et al.* (1996) on the effect of weed frequency on bunch weight in Nigeria who determined that plantain yield decreases in areas where it rains all the year from 16.6tons/ha using 24 weeding/year to 2.5tons/ha using 4 weeding/year.

CONCLUSIONS

In eastern DR Congo banana farmers allocate large portions of their fields to beer making types and have adopted new cultivars, e.g. Cavendish to be part of this group. The preference for beer banana is driven by a need to avoid marketing problems associated with other banana types, since after transformation into juice and beer; the products can be conserved for longer time to generate more income.

The high market demand has increased the cultivation of dessert banana to the second most grown type followed by cooking and roasting banana (plantains) in South Kivu, while in North Kivu the second most grown type is cooking banana followed by roasting and dessert banana. Among the banana types, Nshikazi (AAA-EA-beer) and French plantain Nguma (AAB) are the most preferred cultivars in South Kivu and North Kivu, respectively.

The major criterion of selecting banana cultivars is the flavour/taste, juice production capacity and bunch size. The outbreak of banana *Xanthomonas* wilt has introduced the resistance to disease as part of major selection criteria. Some banana types such as horn plantain that have only one hand per bunch and EAHB-cooking types that have very short fingers and small bunch are grown only by a certain category of farmers (*Bashamuka*). Other cultivars such as Yangambi km 5, Kamelamasengi (Kalole), Musheba (Nguma), Cavendish (Malaya or Kitika sukari kiri), green red (Cisukari or kirisirye), Barhabesha (Mudjuva), Ndundu (Tuntu) are widely grown under several names by all farmers.

Farmers use hand hoes for weeding. The results suggest that planting suckers from existing fields spreads pests and diseases. Low banana yield experienced in the area is due to degeneration of local cultivars, inappropriate banana management and high pest infestation levels. Thus there is need to introduce improved banana cultivars and extension services on integrated pest management. The mixed cropping systems need investigation in order to determine the optimal combinations.

5 ACKNOWLEDGEMENTS: The authors would like to thank the Canadian International Development Agency (CIDA) (through Bioscience in east and central Africa Network/NEPAD) for funding this research. We would also like to thank Wimba Mumbalima for helping during the collection of data.

6 REFERENCES

Agri-Net G, 2009. Farmers Manual of plantains production. Ministry of Agriculture, Guyana. 21pp.

Bakelana K, and Makangidila K, 1996. Country Report: The State of Banana in Zaire. INERA, Kinshasa. 20pp.

Blomme G, Sebuwufu G, Addis T and Turyagyenda LF, 2008. Relative performance of root development in enset and East African highland bananas. African Crop Science Journal 16(1): 51-58.

Chabrier A, Carle C, Quénéhervé P, Cabidoche Y, 2008. Nematode dissemination by water leached in soil: Case study of *Radopholus similis* (Cobb) Thorne on nitisol under simulated rainfall. Applied soil ecology 40: 299-308.

CIA, 2009. "Central Intelligence Agency World fact books" https://www.cia.gv/library/publications/the-world-fact book/.

Delveaux B, 1995. Soils. In: Bananas and Plantains. Gowen, SR (Ed.). Chapman&Hall, London. pp. 230-257.

Dens KR, Romero RA, Swennen R and Turner DW, 2008. Removal of bunch, leaves, or pseudostem alone, or in combination, influences growth and bunch weight of ratoon crops in two banana cultivars. Journal of Horticultural Science & Biotechnology 83 (1): 113–119.

DSRP, 2008. Strategic document for growth and poverty reduction. SK Province, Bukavu, DRC. 68pp.

Ecktein K, Robinson JC, Davie SJ, 1995. Physiological responses of banana (Musa AAACavendish sub-group) in the subtropics. Gas exchange, growth analysis and source-sink interaction over a complete crop cycle. J. Hor~.S c'i (70): 169-180.

Engels JMM, Arora RK, Guarino L, 1995. An introduction to plan germplasm exploration and collecting: planning, methods and procedures, follow-up. In: Collecting Plant Genetic Diversity, Technical Guidelines. Guarino L. *et al.* (Eds). CABI/IPGRI, Rome. Pp 31-63.

Farrow A, Busingye L, Bagenze P, 2006. Characterisation of Mandate Areas for the Consortium for Improved Agricultural Livelihoods in Central Africa (CIALCA). Bukavu. 132pp.

GPC, 2008. Global Plant Clinic. www.globalplantclinic.org. (site visited on October 5, 2008)

Jagwe J, Ouma E, Van Asten P, and Abele S, 2008. Banana Marketing in Rwanda, Burundi and South-Kivu. CIALCA Project Survey Report. Bujumbura. Pp. 61.

Karamura D, 1999. Numerical taxonomic studies of the East African Highland Bananas (*Musa* AAA-East African) in Uganda. Thesis for Award PhD Degree at University of Reading, Reading, UK. 192pp.

Lusty C, Akyeampong E, Davey MW, Newilah N and Markham R, 2006. A staple food with nutritious appeal. Info*Musa* 15 (1-2): 39 – 41.

Mak C, Mohamed AA, Liew KW, Ho YH, 2007. Early screening technique for Fusarium wilt resistance in banana micro propagated plants. FAO, Rome. 10pp.

Michigan DA, 2008. Generally Accepted Agricultural and Management Practices for Manure Management and Utilization. Michigan Commission of Agriculture, Lansing. 45pp.

Ministry of Planning 2005a. Monograph of North-Kivu Province, Piloting Unit of DSRP Process. Kinshasa-Gombe, DRC. 155pp.

Ministry of Planning 2005b. Monograph of South-Kivu Province, Piloting Unit of DSRP Process. Kinshasa-Gombe, DRC. 129pp.

Molina G, 2007. Mitigating the threat of banana Fusarium wilt. INIBAP, Rome. 4p.

Munroe LA, 2009. Insect pests of plantain and banana. NARI, Guyana. 15pp.

Page AL, 1982. Methods of Soil Analysis Part 2. Mandison, Wisconsin, USA. American Society. Inc.1159pp.

Pecrot A, 1958. Carte des sols et de la végétation du Congo Belge et du Rwanda Urundi. 16 Dorsale du Kivu. A. sols, carte de reconnaissance. (Soils and vegetation's map of Congo Belgium and Rwanda Urundi. 16 Ridge of Kivu. A. Soils, recognitions map). INEAC, Bruxelles.

PNUD, 2009a. The unit of poverty reduction of North-Kivu province: Summary profile of poverty and households' livelihood. PNUD, Kinshasa-Gombe, DRC. 20pp. www.undp.org.cd

PNUD, 2009b. The unit of poverty reduction of South-Kivu province: Summary profile of poverty and households' livelihood. PNUD, Kinshasa-Gombe, DRC. 20pp. www.undp.org.cd

Robinson JC 1996. Bananas and Plantains. CAB International, Wallingford, Ox10 8DE, UK. 238pp.

Sebasigari K, 1987. Morphological taxonomy of *Musa* in Eastern Africa. In: Banana and Plantains Breeding Strategies. Persley, G.J.& De Langhe E.A.(Eds). Proceedings of an International Workshop held at Cairns, Australia 13-17 October 1986. pp. 172-176.

Stover RH, and Simmonds NW, 1991. Bananas, Tropical Agriculture Series, third edition. Longman Scientific & Technical, London. 468pp.

Tenkouano A, Vuylsteke D, Swennen R, 2007. Sink Competition and Desuckering Effects on Field Performance of Triploid and Tetraploid Plantain Genotypes. *Journal of crop science improvement* 20 (1-2): 31-51.

Yamaguchi J and Araki S, 2003. Biomass production of banana plants in the indigenous farming system of the East African Highland. A case study on the Kamachumu Plateau in northwest Tanzania. *Agriculture, Ecosystems and Environment.* (Article in Press). Pp 1-19.

Figure 7: See link