

## MANGO CULTIVAR DIVERSITY AND ITS POTENTIAL FOR IMPROVING MANGO PRODUCTIVITY IN KENYA

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### Abstract

Mango (*Mangifera indica* L.) is one of the high potential fruits in Kenya, suitable for different agro-ecological zones ranging from sub-humid to semi-arid. Despite the still growing economic importance of mango in Kenya, its production potential has not yet been fully exploited. This is partly due to lack of knowledge about the most suitable mango varieties for the diverse agro-ecological zones. In addition, the existing introduced and local varieties may not be the most suitable ones. A high intra-specific diversity of mango is essential as a basis for breeding activities and for selecting suitable varieties. Kenya does not have detailed information on mango varieties in the country. The objectives of this study were to document mango varieties at selected motherblocks, nurseries and farms in Central and Eastern Kenya and to combine results of this pilot study with secondary data. The pilot study was conducted at three Kenya Agricultural Research Institutes (KARIs), five prison farms and six individual farms. All mango varieties were recorded and individual trees were counted. In addition, interviews of selected key stakeholders and a literature search were performed. A total of 50 mango varieties were found in the surveyed motherblocks. Per location, 10-36 varieties were observed with a mean of 21. Many of these 50 varieties originated from Florida, Israel or Indonesia/Philippines and were introduced in Kenya in the 1980's. Five varieties, the local ones Apple and Ngowe, and the Florida varieties Kent, Sensation and Tommy Atkins, were the most frequent and abundant ones in the surveyed motherblocks, whereas many of the other mango varieties were neglected. In the surveyed nurseries, a total of 20 mango varieties were found, but only five varieties were produced in large numbers (Apple, Kent, Ngowe, Tommy Atkins and Van Dyke). Thus, a quite large portion of the available genetic resources was not used accordingly. The surveyed farmers cultivated three to six different mango varieties with a mean of 4.8 varieties per farm. Apple, Kent and Tommy Atkins were the most frequent and abundant varieties. These findings corresponded well with results from the literature search, where the varieties Apple, Haden, Kent, Ngowe, Sensation, Tommy Atkins and Van Dyke were given as most important in Kenya. Interviewees mentioned many challenges for their mango business such as problems with pests and diseases, lack of finance, low quality of harvested fruits, too short harvest season and lack of quantity of fruits for processing. These constraints could be addressed by (i) evaluation and characterisation of available rootstock and scion varieties to select the most suitable ones, (ii) importing mango varieties from advanced mango producing countries, and (iii) improving varieties by systematic breeding programs for their better adaptation to present and future environmental and socioeconomic conditions in Kenya.

**Keywords:** conservation of genetic resources, intra-specific diversity, mango variety, motherblock, nursery

### Introduction

Mango (*Mangifera indica* L.) is one of the high potential fruits in Kenya, suitable for different agro-ecological zones ranging from sub-humid to semi-arid (Griesbach, 2003). In 2005, Kenya produced about 250,000 metric tons of fresh mango (HCDA, 2008). This amount has almost doubled to about 450,000 metric tons in 2008, due to expansion of mango area as well as increasing productivity (J.T.A Oduongo, Ministry of Agriculture, personal communication, 2010). However, only 1,800 metric tons of the mango produced were exported in 2009 (HCDA, 2010). Both domestic and export markets are probably not sufficiently supplied with the demanded quantity and quality of mangos, but no detailed data on this are available. Despite the still growing economic importance of mango in Kenya, its potential has not yet been fully used, and mango production struggles with several constraints along the whole value chain.

One of the challenges is the small number of commercial mango varieties grown in Kenya, where mango production is mainly based on less than 10 varieties, mostly introduced ones. Local mango varieties are mainly grown in the coastal area. The other important commercial mango varieties were introduced in Kenya from Florida, Australia, Israel and other countries in the 1980s (Griesbach, 2003). Some of them are not yet fully evaluated and disseminated. As a result, farmers sometimes grow mango varieties that are not very suitable for the respective agro-ecological zone. The commercial varieties often experience pest and disease problems; and frequent application of fungicides and insecticides is necessary to obtain a reasonable harvest. A second challenge is the high seasonality of the mango production. The fruiting season of the improved commercial

varieties starts in November and ends in March with a peak in December and January. During the peak season, prices for mango fruits at farm gate are very low; and losses of fresh fruits that are not harvested or transported are said to be quite high. Throughout the rest of the year, unimproved coastal mango varieties are available at the markets in small amounts together with some off-season fruits of a few improved varieties.

For selecting the most suitable varieties for successful mango production in the different agro-ecological zones of Kenya, a high intra-specific diversity of mango and detailed knowledge about the characteristics of each variety are essential. In Kenya, both the available varieties as well as their characteristics are not yet documented in detail. Maintaining as many mango varieties as possible is also necessary as a basis for national breeding activities, which allows for the development of better adapted and pest/disease-tolerant varieties with a high value for domestic and export markets. Whereas in other mango-producing countries such as India, South Africa and Brazil, mango breeding is highly advanced, Kenya lacks such activities so far.

The objectives of this study were to perform a pilot study in Central and Eastern Kenya to document the mango varieties available at motherblocks and nurseries of governmental institutions, and to gather general knowledge on mango varieties grown by Kenyan farmers and used by exporters and fruit processors for detecting both unused improvement potentials and challenges faced by the different stakeholders of the mango value chain.

## Materials and Methods

For gathering general information on mango production, grown varieties and potentials/challenges along the mango value chain, both a literature search and interviews of selected key stakeholders were performed between January and June 2010. About three to five respondents were selected from each of the sectors of national agricultural research centres, mango farmers, tree nursery operators, mango exporters and processors. For conducting the individual interviews, semi-structured questionnaires were developed, including questions on farm/company size, production data, used varieties, sources of material and constraints of production, among others. For data analysis, only the most important information was used to give an overview. The literature review focussed on mango-related reports of NGOs and KARI, internet searches and available publications from libraries. In addition, six individual farmers were interviewed in a pilot study regarding the mango varieties on their farms. Three farmers were each selected in Ithanga (Thika District, Central Kenya) and in Embu (Embu West District, Eastern Kenya). The altitude of the two locations ranges from 1000-1300 m asl.

For the pilot study on mango varieties available in motherblocks, three KARI centres (Thika, Katumani, Embu) and five prison farms (Ruiru, Kamiti, Maranjau, Mwea, Embu) were selected within a radius of about 100 km around Nairobi, covering both Central and Eastern Kenya. The climate of the surveyed locations is semi-arid to sub-humid (mean annual precipitation 750-1300 mm), the altitude ranges from 1100-1600 m asl. The selection was based on the information that well established mango motherblocks as well as fruit tree nurseries are present at the same locations.

In the eight motherblocks, all mango varieties were recorded and the tree individuals per variety counted. Shannon index and Shannon evenness index were calculated as measures of diversity by using MVSP (Multi-Variate Statistical Package, version 13.3p, Kovach Computing Services; Anglesey, Wales, UK). Data on mango varieties produced in nurseries of the same eight locations were gathered during individual interviews of the nursery managers. Statistical analyses, performed by SPSS (version 12.0) included *T*-tests for detecting differences of mango variety number and diversity indices between the motherblocks of the two types of locations (research stations vs. prisons) and between motherblocks and nurseries.

## Results

### *Pilot study on mango varieties in motherblocks of Central and Eastern Kenya*

In motherblocks at the surveyed eight locations, a total of 50 mango varieties were found (Table 1), ranging from 10-36 varieties per location with a mean of 21. KARI-Thika had the

**Table 1. List of all mango varieties found at the surveyed motherblocks in Central and Eastern Kenya, including their origin, number of trees per variety and location as well as in total, and frequency of occurrence per variety.**

No.	Name	Origin	Location								Frequency	Total no. of trees
			KARI-Thika	KARI-Embu	KARI-Katumani	Ruiru Prison	Maranjau Prison	Embu Prison	Mwea Prison	Kamiti Prison		

1	Alphonso	India	3	3	1	2	5		1		6	15
2	Apple	Kenya	1	2	19	7	235	280	20	15	8	579
3	Azucar	Brazil?	2								1	2
4	Bangallossa	Kenya?			1						1	1
5	Batawi	Kenya				6	2		10	15	4	33
6	Boribo	Kenya			1	3	2	44	7	9	6	66
7	Cerebau	Philippines	2				1		2		3	5
8	Chino	Unknown	2			12	1				3	15
9	Dodo	Kenya				2	6		7	9	4	24
10	Edward	Israel	3								1	3
11	Galek	Indonesia	1								1	1
12	Gesine	?				14	5		1	3	4	23
13	Glenn	Florida?	14								1	14
14	Golek	Indonesia	1						2	3	3	6
15	Haden	Florida	1	4	10	3	58	13	50	87	8	226
16	Harumanis	Indonesia	2								1	2
17	Heart	Indochina	1			2			7		3	10
18	Irwin	Florida	15							2	2	17
19	Keitt	Florida					22		1		2	23
20	Kensington	Australia	2		1				1	5	4	9
21	Kent	Florida	7	8	4	16	263	35	45	132	8	510
22	Local Variety	Kenya?			6		40				2	46
23	M-10310	?	2								1	2
24	M-17449	?	12								1	12
25	M-17697	?	11								1	11
26	M-17728	?	10								1	10
27	M-26403	?	11								1	11
28	Madu	Indonesia	1								1	1
		West										
29	Matthias	Africa?				15			4	4	3	23
30	Maya	Israel	12		3	2	1			13	5	31
31	Nimrod	Israel			4		1			1	3	6
32	Ngowe	Tanzania	10	3	3	3	125	110	17	38	8	309
33	Ono	Hawaii?	2								1	2
34	Palmer	?	6								1	6
35	Parwin	Florida	1				4			5	3	10
36	Peach	South Africa	11			10		21	7	15	5	64
37	Rose	?			1						1	1
38	Sabine	Kenya	3	5		15	12	88	10	7	7	140
39	Sabre	South Africa	35	10	1	17	39	27	3	44	8	176
40	Sensation	Florida	2	4	1	43	56	8	45	194	8	353
41	Smith	Hawaii				2					1	2
42	Terpentine	West Indies?	7								1	7
43	Tommy Atkins	Florida	21	8	15	16	432	16	7	185	8	700
44	Unknown/local	?					78				1	78
45	Van Dyke	Florida	28	9	8	16	88	25	9	31	8	214
46	Zill	Florida					3			10	2	13
47	Zillate	Florida				6	6			15	3	27
48	Zulu	South Africa	10				15		1	4	4	30
49	13-1	Israel?	6								1	6
50	13-42	?	2								1	2
		No. of varieties	36	10	16	21	25	11	22	24		

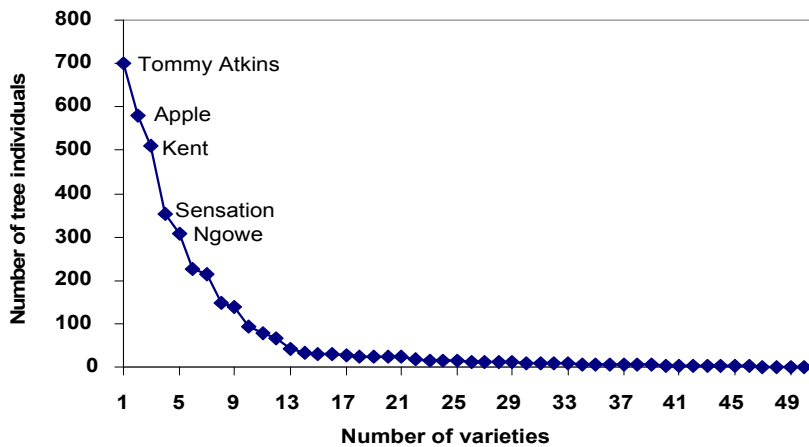
most diverse motherblock with 36 different varieties (Table 2). Among the prisons, Maranjau and Kamiti had the largest motherblocks planted with 1500 and 846 individual trees, respectively, whereas the KARI centres Embu and Katumani had the smallest ones, harbouring only 56 and 79 trees of 10 and 16 varieties, respectively. Shannon diversity was highest in the KARI-Thika and lowest in Embu Prison, whereas evenness was highest in the KARI-Embu and lowest in Maranjau Prison (Table 2). No significant differences in number of varieties, tree individuals or diversity indices were found between the research stations and the prison farms.

**Table 2. Numbers of varieties and tree individuals per variety as well as varietal diversity indices of the surveyed eight motherblocks around Nairobi, Central and Eastern Kenya.**

Location	Category	No. of varieties	No. of trees	Shannon index	Shannon evenness
KARI-Thika	Research station	36	260	3.11	0.87
KARI-Embu	Research station	10	56	2.18	0.95
KARI-Katumani	Research station	16	79	2.29	0.82
Ruiru Prison	Prison farm	21	212	2.69	0.88
Maranjau Prison	Prison farm	25	1500	2.22	0.69
Embu Prison	Prison farm	11	667	1.97	0.79
Mwea Prison	Prison farm	22	257	2.47	0.80
Kamiti Prison	Prison farm	24	846	2.32	0.73
	Mean research stations	20.7a	132a	2.53a	0.88a
	Mean prison farms	20.8a	696a	2.31a	0.77a

Means in a column followed by different letters are significantly different at  $P < 0.05$  (T-test).

Many of the 50 varieties maintained in the surveyed motherblocks originated from Florida (11), Israel (6) or Indonesia/Philippines (6) and were introduced in Kenya in the 1980's. A large portion of the commercial Florida and Israel varieties was introduced at the mentioned time by Mr. Juergen Griesbach in the frame of a project for improving fruit production in Kenya, financed by GTZ (German technical aid organization) (J. Griesbach, pers. comm., 2010). Eight of the 50 varieties in the surveyed motherblocks were of Kenyan or Tanzanian origin. More local Kenyan varieties are expected to exist in the region, but these were not represented in the surveyed motherblocks. Only seven out of the 50 varieties were found in all of the surveyed motherblocks, namely the local varieties Apple and Ngowe, and the Florida varieties Haden, Kent, Sensation, Tommy Atkins and Van Dyke. Two more varieties were found at seven of the eight motherblocks, the variety Sabine from Kenya and the rootstock variety Sabre from South Africa. Apart from these very frequent varieties, 20 varieties were only maintained in a single location each. The frequent varieties were also the most abundant ones. Five dominant varieties, Apple, Kent, Ngowe, Sensation and Tommy Atkins were present with more than 300 total individual trees each (Figure 1). On the other hand, for 18 rare varieties such as Azucar, Kensington, Ono, Palmer or Rose, less than 10 trees each were counted in total.



**Fig. 1: Variety-rank curve of mango varieties in eight motherblocks around Nairobi, Central and Eastern Kenya**

**Pilot study on mango varieties in nurseries of Central and Eastern Kenya**

All of the surveyed motherblock locations had their own tree nursery to supply mainly small scale farmers, but also large farms and projects in the same area. The nurseries were founded between 1970 and 1992, partly in the frame of the above mentioned GTZ project to promote fruit production in Kenya. The respondents mentioned a

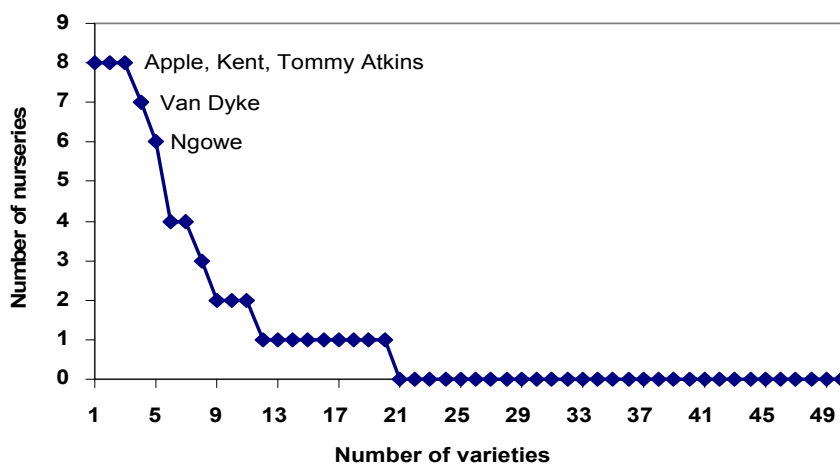
total of 20 mango varieties in their nurseries, but only five varieties were produced in large numbers for sale – three Florida varieties (Kent, Tommy Atkins, Van Dyke) and two Kenyan varieties (Apple, Ngowe) (Table 3). The latter are in growing demand in Kenya for juice production (and seasonally for export), whereas the former are mostly used as fresh fruits for supplying both domestic and export markets. The number of mango varieties offered per nursery ranged from 5-15 with a mean of eight. No significant differences of the variety number were found between nurseries of research stations (mean=6.3) and prison farms (mean=8.8).

**Table 3. Percentages of mango seedlings of different varieties produced in eight nurseries around Nairobi, Central and Eastern Kenya.**

Location of the nursery	Main varieties							Other varieties in small quantity (partly on order)
	Apple	Ngowe	Tommy A.	Van Dyke	Kent	Haden	Sensation	
KARI-Thika	+++	+	++++	++	+	++		None
KARI-Embu*	++	++	++	++	++			None
KARI-Katamani*	++	++	++		++		++	Alphonso, Maya, Nimrod
Ruiru Prison	+++		+++	+	++			Chino, Sabine, Zillate
Maranjau Prison	+++	+	++++	+	++		+	Sabine, Zulu
Embu Prison	++++	+	+	+	+	+	+	Boribo, Batawi, Heart, Dodo, Peach, Sabre, Zulu, Sabine
Mwea Prison	+++	++	++	+	++++	+	+	None
Kamiti Prison	+++		+++	+	++			Maya, Sabine, Zillate

\* For KARI-Embu and KARI-Katamani, no percentage was given, but only the 'most demanded' varieties.  
++++= 50% or more  
+++ = 20-40%  
++ = 10%  
+ = less than 10%

The same most abundant five varieties were also the most frequent ones, being produced in at least six of the surveyed eight nurseries (Figure 2). Nine varieties were offered in only one nursery each and 30 of the varieties maintained at the motherblocks were not at all available in the surveyed nurseries. For raising rootstocks, mainly seeds of the varieties Sabre and Peach, but also of a mixture of local varieties were used.



**Fig. 2: Variety-frequency curve of mango varieties produced in eight nurseries around Nairobi, Central and Eastern Kenya.**

**Pilot study on mango varieties cultivated on farms of Central and Eastern Kenya**

The surveyed farmers cultivated three to six different mango varieties with a mean of 4.8 varieties per farm (Table 4). Apple, Kent and Tommy Atkins were the most frequent and abundant varieties. Mango tree density ranged from 14-40 trees per acre with a mean of 25.6. The mango trees were cultivated in an agroforestry

system in a diverse mixture with maize, bean, avocado, citrus species, fodder species and timber trees, among others. Farmers had a positive opinion on mango cultivation; most of them wanted to plant more mango trees in the future, one wanted to start his own mango nursery. The main challenges for mango cultivation mentioned by the farmers were pests and disease problems, financial constrains (e.g. for buying pesticides) and marketing problems due to the strong seasonality of mango production and the lack of sufficient exporters and processors in the area.

**Table 4. Characteristics and mango varietal diversity (variety number, tree individual numbers per variety and in total, tree individuals per acre) at six farms surveyed in Ithanga and Embu, Central and Eastern Kenya**

Farm no.	Loca-tion	Farm size (ac)	Varieties							Total varie-ties	Tree ind.	Trees per acre		
			Alphonso	Apple	Haden	Kent	Local	Ngowe	Sabine				Tommy A.	Van Dyke
1	Ithanga	8.0	18			22	4	10		120	20	6	194	24.3
2	Ithanga	1.2	25			7		4		4		4	40	33.3
3	Ithanga	7.0	13	1		39		1		56	4	6	114	16.3
4	Embu	NA	2		4	8			3	10	13	6	40	NA
5	Embu	2.5		74	5	21						3	100	40.0
6	Embu	5.0		25		25		10		10		4	70	14.0
	Sum		2	155	10	122	4	25	3	200	37			
	Mean	4.7										4.8	93.0	25.6

#### *Pilot study on mango varieties for export and processing companies*

All three mango export companies included in this pilot study mentioned to export their fruits exclusively to the Middle East countries such as United Arab Emirates (UAE) and Saudi Arabia. According to the respondents, the European Union (EU) market does not allow the import of Kenyan mangos because they do not fulfil the EurepGAP norms due to quarantine issues and pesticide residues. Certification and inspection services are required for all mango shipments and executed by Kenya Plant Health Inspectorate Services (KEPHIS) and Horticultural Crops Development Authority (HCDA). Respondents mentioned that consumers in the Middle East countries rather prefer big, sweet and juicy mangos and do not care much about skin colour, whereas smaller mangos with orange to red skin colour would be demanded by European consumers. The variety mostly requested for export by the three companies is Apple mango, followed by Ngowe (Table 5). Florida varieties such as Kent, Tommy Atkins and Van Dyke were only exported in small quantities.

Two companies reported to buy fruits from contract farmers, including both small and large scale ones (Table 5). The other one bought fruits from any farmer or broker offering mangos at the company's gate. The reason given for not having contract farmers by this company was lack of trust due to former negative experiences. The purchased mangos may have been grown either close to the company or as far away as at the coast. Main challenges for the mango export business given by the respondents were (i) inadequate quality and quantity of delivered mangos, (ii) financial constraints and (iii) lack of sufficient cold storage facilities. Seasonality of the mango was not mentioned as a constraint because all three companies are exporting other commodities such as avocados, nuts and vegetables in addition to mangos.

**Table 5. Mango varieties and sources of the fruits for three mango export companies surveyed in Central Kenya.**

Company name	Varieties			Working with contract farmers	Sourcing fruits from far
	Apple	Ngowe	Others*		
Keitt Ltd.	70%	10%	20%	Yes	No
East African Growers	45%	45%	10%	No	Yes
Vegmon	60%	20%	20%	Yes	Yes

\* Includes Keitt, Kent, Sabine, Tommy Atkins and Van Dyke.

The two mango processing companies included in this pilot study, Sunny Processors and Kevian, both manage their own fruit farms of 250 and 60 acres, respectively, where they mainly grow Tommy Atkins, Ngowe and

Kent mangos, among smaller numbers of Apple, Alphonso, Maya, Haden, Keitt, Sabine and Van Dyke. Respondents mentioned that the supply from their own mango farms is inadequate to meet the factory's demand. Thus, they buy large amounts of fresh mangos from brokers and directly from small and large scale farmers; Kevian also buys from farmer groups. The most demanded varieties for processing were Ngowe and Apple, partly also Kent and Tommy Atkins. The produced mango pulp was either mainly exported (Sunny Processors) or sold at the domestic market (Kevian). Both processing companies mentioned to be challenged by (i) not sufficient quantity and quality of fresh mango fruits and (ii) high production costs, partly due to high taxes and fees, resulting in high prices for the end product. To overcome the mango supply constraints, Kevian planned to promote a mango out-grower scheme close to their factory, whereas Sunny Processors mentioned the need for new and better mango varieties (early and late ones) that extend the harvest season.

#### **Literature search on mango varieties grown in Kenya**

According to most of the literature available on mango cultivars grown in Kenya, only about five to seven varieties are commonly grown. The 'Report on the Mango Value Chain Stakeholder Workshop' by MoA/GTZ (2006) mentioned the five varieties Apple, Kent, Ngowe, Tommy Atkins and Van Dyke as most frequently grown by the 16 surveyed farmers participating in the PSDA project. Njuguna *et al.* (2009) reported seven main varieties in Kenya, namely the local varieties Apple and Ngowe and the introduced ones Haden, Kent, Sensation, Tommy Atkins and Van Dyke. However, none of these publications included details on acreages or production data per variety, neither were they based on extensive surveys of mango farms. Griesbach (2003), although listing 31 mango cultivars available in Kenya, classified only seven varieties (Haden, Kent, Maya, Ngowe, Sabine, Sensation, Van Dyke) as important that he carried out evaluation trials on their performance.

A detailed survey on the cultivated mango varieties was only performed for the Coast Province by ABD and DANIDA (2009), published in their report on 'The Results of the Mango Tree Census and Baseline Survey for Coast Province'. The survey was carried out from Sep-Nov 2009, when almost 81,000 farmers were interviewed on total population of mango trees in their farm as well as trees per variety, age of trees and sources of planting material. According to the report, 50% of all mango trees in Coast Province were Ngowe, 19% Kienyeji (local variety), 17% Apple, 12% Boribo, 2% Batawi and only 0.4% introduced varieties (e.g. Kent, Tommy Atkins, Sensation, Van Dyke). Only 5% of the mango trees in Coast Province were grafted. Concerning the main source of their planting material, 39% of the respondents planted seeds directly, 30% just relied on self germinated seedlings from natural regeneration and an additional 17% planted seedlings raised in their own nursery. The major constraints for mango production mentioned by the surveyed farmers were pest and disease problems, however, only 8% reported to apply pesticides due to the high cost. In addition to poor orchard management, respondents also stressed overage orchards, too tall trees and unsuitable varieties as further challenges. Consequently, one of the recommendations given by the ABD and DANIDA report (2009) was to request 'agricultural research institutions to spearhead initiatives for development of quality and sufficient mango cultivars suitable for coast region and make them available to the farmers' by improving farmers' access to quality planting materials.

#### **Discussion**

Mango varietal diversity in the surveyed motherblocks was relatively high with 50 different varieties. Compared to other mango producing countries, however, the number of varieties in Kenya is quite small. In India, for example, about 1000 different mango varieties are said to exist (Karihaloo *et al.*, 2003); in Nepal a survey of Subedi *et al.* (2005b) recorded 132 farmer-named varieties; and in Florida, 208 of the varieties maintained were already characterized by microsatellite marker technique (Schnell *et al.*, 2006).

In Kenya, the very uneven distribution of the 50 mango varieties found in the surveyed motherblocks (few dominant, very abundant varieties, many rare varieties with few individuals; Figure 1) may question the value of these motherblocks for long-term conservation of mango genetic resources. Particularly the rare varieties, of which often less than 10 trees were maintained at only one single location, can be classified as 'threatened'. Particularly in the prison farms, where motherblocks are at the same time production units, minor and less productive varieties may not be maintained in the long-term. Only the KARI centres are currently suitable for conservation of a broad range of mango genetic resources. However, mango varieties should be distributed with sufficient individual numbers per variety to more KARI motherblocks. Systematic characterisation of the different mango varieties, including the minor ones, and evaluation of their performance in different agro-ecological zones of Kenya is still missing for most of the varieties. Results of the varietal evaluation will contribute to give farmers better recommendations on the most suitable mango varieties for their respective farm environment.

Detailed and well documented information about the available genetic material together with a broad, well maintained varietal diversity are essential for breeding efforts. This should also include local varieties (Subedi *et al.*, 2005a), which may have a low market, but high breeding value. In addition to using morphological descriptors for variety characterisation (IPGRI, 2006), molecular marker and isozyme analysis techniques are increasingly used for describing the genetic diversity of mango cultivars (Karihaloo *et al.*, 2003; Subedi *et al.*, 2005b; Schnell *et al.*, 2006; Yamanaka *et al.*, 2006; Krishna and Singh, 2007; Díaz-Matallana *et al.*, 2009). In the main mango producing countries such as India and Brazil, breeding of mangos is a priority of national horticultural research institutions as shown by the successful breeding programs and releases of improved hybrid varieties in the mentioned countries (Iyer and Schnell, 2009; Pommer and Barbosa, 2009). In Kenya, mango breeding is so far neglected, but urgently needs to be addressed to improve the existing commercial varieties for processing, export and the domestic market. As a result from this study, Kenyan breeding programs should focus on developing varieties, which are (i) pest and disease tolerant to reduce both farmers' input costs and pesticide residues, (ii) early and late harvesting to extend the harvest period, (iii) having an orange to red skin colour and strong structure to improve marketing and increase transport length, and (iv) drought and salt stress tolerant to enable adaptation of mango farming systems to climate change.

The nursery pilot study showed that a quite large portion of the available genetic resources are not used accordingly. Seedlings of only five out of the 50 varieties maintained in motherblocks were produced in larger numbers by the surveyed nurseries. As detailed information about the most suitable varieties for a certain agro-ecological zone is usually missing, too (see above), farmers may not be supplied with the most productive material. Although the use of homogenous, well documented material for rootstocks is highly recommended (Ram and Litz, 2009), some of the surveyed nurseries still used mixed local mango varieties as source for their rootstock. This will definitely result in low quality planting material, as the rootstock strongly influences the performance of the grafted variety (Ram and Litz, 2009). Mango productivity in Kenya can thus be improved by using the most suitable rootstock for the different climate and soil conditions. However, available rootstock varieties in Kenya and their characteristics are not yet studied and documented in detail. Another problem in Kenya is the poor dissemination of quality planting material to mango farmers. Even the surveyed governmental nurseries could not meet the high demand of farmers for grafted mango seedlings. In many rural areas, where mango cultivation has a high potential, no fruit tree nurseries are available. Development of an efficient and sustainable system for supplying interested farmers with high quality mango planting material of the most suitable varieties together with information on good management practices is urgently needed to increase Kenya's mango production and productivity.

## Conclusions and Recommendations

Kenya with its diverse agro-ecological zones is very suitable for almost year-round production of high quality mango fruits to meet the increasing demands of domestic and export markets for fresh and processed fruits. However, Kenya's potential for mango production is not yet fully exploited. To improve this situation, many issues along the whole mango value chain need to be addressed. Suitable, high quality planting material is a prerequisite for improving the mango value chain. Research on this issue is urgently needed and should focus first on evaluation and characterisation of available rootstock and scion varieties to select the most suitable ones for efficient dissemination to farmers in different agro-ecological zones. Second, the number of mango varieties should be increased by importing material from advanced mango producing countries. Finally, the most promising mango varieties need to be further improved by systematic breeding programs for their better adaptation to present and future environmental and socioeconomic conditions in Kenya.

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