Vol. 14(4), pp. 185-196, 24 January, 2019
DOI: 10.5897/AJAR2018.13608
Article Number: E6FBB0859987
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

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African Journal of Agricultural Research

Full Length Research Paper

Mango (*Mangifera indica* L.) production practices and constraints in major production regions of Ethiopia

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Received 5 October, 2018; Accepted 5 December, 2018

Mango (*Mangifera indica* L.) is the second among fruit crops in Ethiopia in its production coverage and economical importance. However, compared to the countries' potential, it is at the infant stage. This study was conducted to identify the main mango cultivars, production practices and constraints in east and western Ethiopia in 2016. Study areas were selected purposively based on their extensive mango production. Thirty-one cultivars of unknown origin were identified based on farmers' characterization criteria. The majority of the farmers were found not to apply fertilizers (63.7%), supplementary irrigation (87.6%), nor prune their mangos (50%). About 50% of growers revealed fruit yield of 100-200 kg/tree and harvest fully ripe. Packaging and transportation of mangos were entirely below the standard. Availability of agricultural inputs such as fertilizers and pesticides, pest, knowledge and skill gap, and availability of improved varieties were the major constraints. Assessment of similarities in terms of farming system, mango production practices, harvest, post-harvest handling, marketing, and their constraints indicated that 76.9% of growers were similar. Therefore, improvement of the pre and post-production practices, utilization and/or conservation of the identified cultivars, and addressing the constraints will be crucial to improving the mango sector in Ethiopia.

Key words: Interview, mango cultivars, tropical fruit, biodiversity.

INTRODUCTION

Mango (Mangifera indica L.) is one of the 73 genera of the family Anacardiaceae and order Sapindales (Ahmed and Mohamed, 2015) which is one of the most versatile and widely grown fruit crops of tropical and subtropical regions (Vasugi et al., 2012). It is believed to have originated from South East Asia and more than 1000 varieties have been identified all over the world (Rymbai et al., 2014). Mango is cultivated approximately on 3.7 million hectares worldwide, occupied the 2nd position among the tropical fruit crops (Jahurul et al., 2015) and

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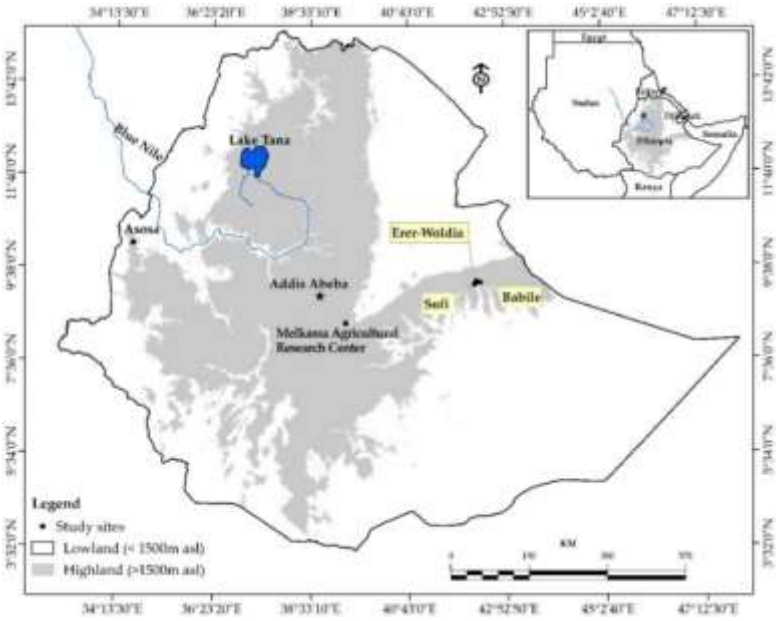

Figure 1. Geographic locations of surveyed districts in the east and western Ethiopia.

5th from fruit crops of the world after citrus, banana, grape, and apple (Shi et al., 2015). Asian countries share the largest (77%) of global production, followed by Americans (13%) and African countries (10%) (Rekhapriyadharshini, 2015). Mango is known as the king of the fruits due to its excellent flavor, delicious taste and high nutritive values (Ullah et al., 2010) that makes the crop valued for both food and nutritional security especially for developing countries like Ethiopia where the realization of food and nutritional security is still a challenge.

Mango is one of the most widely grown among the fruit crops cultivated in Ethiopia preceded only by banana in terms of economic importance (Fita, 2014). A total of 69,743.39 tons of mango is produced from 12,799 ha of land (CSA, 2015). Moreover, within the past 10 years (2003 to 2013), both area coverage and production of mango increased by 208.4 and 247%, respectively (Dessalegn et al., 2014). It is grown in several parts of the country where the western and eastern Ethiopia are among the major producing belt that accounts >50% of the total mango production in Ethiopia (CSA, 2015).

Despite the crop potential to contribute to improved nutritional status and health of the Ethiopian society, the national average production yield is about 7 ton/ha and, in some region like Amhara, it is estimated to be 3.5 ton/ha (Dessalegn et al., 2014). Though the productivity of the crop is governed by various factors like genetic and/or enviromental variables, the productivity in the country is very low compared to the crop potential, about 20-30 ton/ha (Griesbach, 2003; Tiwari and Baghel, 2014). The recently introduced export-oriented horticulture policy of the government is in the process of replacing farmers' indigenous cultivars with the introduction of improved commercial mango varieties. There are few studies which have reported on the practices and constraints of mango production in Ethiopia in the past (Dessalegn et al., 2014; Fita, 2014; Hussein and Yimer, 2013). However, none of them identified the farmers' mango cultivars and the depth of generated information with regard to pre and post production practices and marketing especially in the east and western Ethiopia was not sufficient to alleviate the challenges.

In order to come up with conservation strategies for a crop species at a country level, there is need of good knowledge of the existing diversity within the crop and traditional production system to understand the factors that affect this diversity (Bisht et al., 2007). Other than just for conservation, the locally adapted cultivars usually produce stable yields. Nonetheless, their production is generally lower at optimal conditions than ''improved'' cultivars (Yong'an et al., 2010; Xiahong et al., 2011), suitable for low input requirements, and have low susceptibility to pests and high drought tolerance (Shi et al., 2015) . This study was conducted with the objective of assessing the existing cultivars, production practices and constraints of mango in major production regions of Ethiopia.

MATERIALS AND METHODS

Study areas

The study was conducted in four mango producing districts selected from two geographic regions, viz; Eastern and Western Ethiopia (Figure 1 and Table 1).

Table 1. Details of selected villages and districts.

S/N	Village	Code	Region	District	GPS Coordinate	Altitude (m.a.s.l)
1.	Abdibuch Maru	BA1	Eastern Hararghe Zone, Oromia Regional State	Babile	09°17'59''N 042° 17'26''E	1778
2.	Shekhussien Hajisuffe	BA2	Eastern Hararghe Zone, Oromia Regional State	Babile	09°09'59''N 042°21'11''E	1571
3.	Sheckhussien-Walqebela	BA3	Eastern Hararghe Zone, Oromia Regional State	Babile	09°10'57''N 042°21'33''E	1601
4.	Goromeskida	ER1	Harari People's National Regional State, eastern Ethiopia	Erer-Woldia	09°20'39''N 042°12'37''E	1412
5.	Konya	ER2	Harari People's National Regional State, eastern Ethiopia	Erer-Woldia	09°21'34''N 042°12'50''E	1457
6.	Ganda Bekere	ER3	Harari People's National Regional State, eastern Ethiopia	Erer-Woldia	09°20'55''N 042°12'57''E	1403
7.	Melka Hida	ER4	Harari People's National Regional State, eastern Ethiopia	Erer-Woldia	09°21'22''N 042°13'16''E	1446
8.	Nole	HA1	Harari People's National Regional State, eastern Ethiopia	Sofi	09°16'20''N 042°10'44''E	1589
9.	Agemboy	HA2	Harari People's National Regional State, eastern Ethiopia	Sofi	09°17'04''N 042°10'15''E	1679
10.	Kalu	HA3	Harari People's National Regional State, eastern Ethiopia	Sofi	09°15'45''N 042°11'20''E	1491
11.	Bereser	HA4	Harari People's National Regional State, eastern Ethiopia	Sofi	09°15'45''N 042°10'24''E	1594
12.	Ura	AS1	Benishangul Gumuz Regional State, western Ethiopia	Asosa	10°08'17.4''N 034°39'29.8''E	1485
13.	Amba10	AS2	Benishangul Gumuz Regional State, western Ethiopia	Asosa	10°08'05''N 034°39'17''E	1488

Sampling and data collection

Multi-stage purposive sampling technique was employed in the selection of the study sites based on their representativeness of mango production, geographical locations, experiences, and future prospects in consultation with the Regional/Zone agricultural offices. Accordingly, four districts that encompassed 13 villages were purposively selected (Table 1). A total of 113 mango grower households that represented 15% of the identified potential mango growers of each district, were randomly selected. A semi-structured questionnaire was prepared, pre-tested with trained enumerators and remedial action was made accordingly. Data were collected through individual farmer's interviews using the questionnaire and field observation. It included socio-economics, existing farmers' cultivars, pre, and post-production practices and overall production constraints.

Data analysis

The collected data were summarized and analyzed using Statistical Package for Social Scientists (SPSS) Statistics for Windows, Version 20.0 (IBM, 2011). *Chi*-square test was computed to find if there was differences in production practices and constraints among the districts where the growers were located. The overall dissimilarity/similarity of growers regarding production practices and constraints were analyzed following the widely used Unweighted Pair-Group Method with Arithmetic Mean (UPGMA) cluster analysis method (Sneath and Sokal, 1973)after the data were standardized using z-score transformation method (Ramette, 2007).

RESULTS AND DISCUSSION

Socio-economics of respondents and farming system

A significant number of respondents' had an age range of 30-40 years but a total of 58.4% of respondents had >41 years of age. The majority of the respondents did not attend formal education and partly attended up to primary school (Table 2). Aged and illiterate farmers could be among the barriers to adopt improved technologies (Berg, 2013). Positive correlation between education and technology adoption was also noted by Ogada et al. (2014). Similar results were reported in other parts of Ethiopia like east and west Wolega zones of Oromia Regional State (Fita, 2014) and Amhara National Regional State (Dessalegn et al., 2014).

More than half of respondents owned less than 15 mango trees per household and 61.9% of the respondents had more than 15 up to 30 years mango

Table 2. Demographic characteristics of sampled respondents.

Variable	Districts				Total	$\chi 2^a$
	Eastern Ethiopia			Western Ethiopia		
	Erer	Sofi	Babile	Assosa		
Age :						
30-40	11.0	12.0	22.0	2.0	47(41.6%)	40.0***
41-50	8.0	8.0	10.0	7.0	33(29.2%)	
>50	4.0	3.0	4.0	22.0	33(29.2%)	
Mean	43.7	41.4	40.1	55.8	45.3	
Education level:						
No school	16.0	14.0	18.0	9.0	57(50.4%)	17.9***
Primary school	5.0	8.0	18.0	22.0	53(46.9%)	
Secondary school	2.0	1.0	0.0	0.0	3(2.7%)	

Table 3. Number of mango trees and cultivation experience of respondents.

Variable	Districts				Total	$\chi 2^a$
	Eastern Ethiopia			Western Ethiopia		
	Erer	Sofi	Babile	Assosa		
Mango trees per farm:						
<15	10	9	23	16	58(51.3%)	15.4**
15-30	10	8	13	6	37(32.7%)	
>30	3	6	0	9	18(15.9%)	
Mean	20.0	23.1	13.2	32.1	22.1	
Farming experience in years:						
<15	3	3	2	0	8(7.1%)	10.1^{ns}
15-30	14	14	26	16	70(61.9%)	
>30	3	6	0	9	18(15.9%)	
Mean	27.5	27.5	25.2	34.2	28.6	
Cultivation knowledge source:						
Ancestors/family	23	19	25	19	86(76.1%)	16.2**
Neighbor's	0	4	11	10	25(22.1%)	
Extension agents	0	0	0	2	2(1.8%)	
Reasons for cultivation:						
Best money making	19	22	29	20	90(79.6%)	11.3*
Tradition	4	1	7	9	21(18.6%)	
No alternatives	0	0	0	2	2(1.8%)	
Planting material:						
Seed	23	23	36	31	113(100%)	-
Cropping system:						
Mixed	23	23	36	31	113(100%)	-

[a]*Chi-square* test, ns = not significant,* and ** Significant at $\alpha \leq 0.05$ and $\alpha \leq 0.01$, respectively.

cultivation experience. However, the highest proportion of respondents acquired mango farming knowledge from their ancestors of family members and neighbors, whereas very small proportion (1.8%) of them obtained the knowledge from agriculture extension agents (Table 3). Mango production is an income earner for the majority

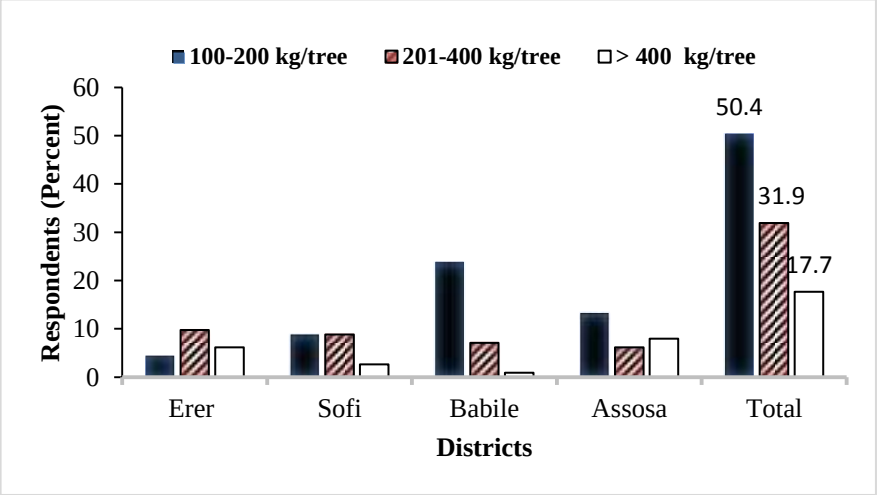

Figure 2. Estimates of mango yield (kg/tree) in the east and western Ethiopia.

of the respondents though some of them (18.6%) grew mango as a tradition. Hence, there is a need for capacity building of the growers by extension agents to improve the farming system (Dessalegn et al., 2014).

Mangos in the study sites were entirely propagated by seed and were under mixed cropping production system (Table 3). Mango can be propagated either by seed or through grafting. However, to guarantee the variety and maximum uniformity, it is essential to using grafting or another asexual method of propagation (Krishna and Singh, 2007). Therefore, the seed propagation might be the reason for the existing variability among the trees in the studied areas (Bally, 2011). The mixed cropping system, that was, growing mango with annual crops like maize, sorghum, beans, groundnut etc., vegetables, and perennial cash crop khat (Catha edulis L.), could be recommended to generate additional income, efficient use, and conservation of resources and diversification of their diet (Tiwari and Baghel, 2014). However, performance and profitability of the existing mango based cropping system should be further studied (Swain, 2014).

Mango cultivars and productivity

Mango cultivars

The cultivars had various local names based on unique features of the fruits (shape, size, color, aroma, taste, and fiber content) and the person introduced in the localities (Table 4). The mango naming in most parts of the world also reflects the grower's culture, languages, origins and spread of the mango tree along with the spread and settlement of communities (Bally, 2011). Due to such diversity in naming, the observed mango trees were mixed and difficult to identify. Consequently, two or more names could exist for the same cultivar. This scenario is similar to Sennhenn et al. (2013) who reported confusion in the identification of Kenyan mango due to local naming.

Seven (22.58%) out of 31 mango cultivars identified in eastern and western Ethiopia were given the name of the person who introduced them to the villages. Since most of the trees were old (more than 50 years), the growers were not sure about the cultivars origin. However, some of the interviewed elders suspected the sources of local mangos in eastern Ethiopia could be from Arab countries introduced by Muslims who used to go to Mecca, and from other countries by traders and missionaries. Whereas the introduction route for western Ethiopia (Asosa) was assumed to be by traders from Sudan.

Mango cultivars productivity

The average yield reported by the respondent farmers was 270 kg per tree where a majority reported 100-200 kg/tree while a few respondents reported more than 400 kg per tree (Figure 2). The reported range of yield was almost comparable with other countries where the productivity of mango ranges from 200 to 300 kg fruits per tree (5.5-33.1 tons/ha) depending on different factors such as variety, tree age, tree size, seasonal conditions, management and previous cropping history (Griesbach, 2003; Tiwariand Baghel, 2014). Therefore, it indicated the presence of high yielding farmers' cultivars in the country that can be considered for future use and/or conservation activities.

Production practices

Agronomic management practices

Planting patterns and fertilizer application: The mango trees in the study sites were planted irregularly (Table 5).

Table 4. Name and distribution of mango cultivars grown in east and western Ethiopia.

Cultivars name	Meaning and basis for naming in the local language	Districts				Total	$\chi 2^a$
		Eastern Ethiopia			Western Ethiopia		
		Erer	Sofi	Babile	Assosa		
Almenga	Meaning mango	0	0	0	31	31(27.4%)	113.0***
AmbaAdi	Fruit color	14	7	17	0	38(33.6%)	26.4***
AmbaAko	Name of introduced person	10	1	3	0	14(12.4%)	26.8**
AmbaArenjata	Texture and taste of fruit	2	0	0	0	2(1.8%)	8.0*
AmbaBere	Name of introduced person	15	7	21	0	43(38.1%)	33.1*
AmbaBishaano	Taste and juiciness of fruit	0	1	0	0	1(0.9%)	4.0^{ns}
Amba Dada	Fruit flush texture when ripe	0	1	0	0	1(0.9%)	4.0^{ns}
AmbaDemma	Taste of fruit	0	1	0	0	1(0.9%)	4.0^{ns}
AmbaDula	Introduced person	0	0	21	0	21(18.6%)	55.2***
AmbaErrero	Origin	0	16	0	0	16(14.2%)	72.9***
AmbaFulla	Shape of the fruit	0	0	1	0	1(0.9%)	2.2^{ns}
AmbaGerjewi	Taste and texture of fruit	1	0	0	0	1(0.9%)	3.9^{ns}
AmbaGuracha	Color of fruit skin when ripe	17	4	14	0	35(31%)	36.8***
AmbaHarewe	Origin	10	0	0	0	10(8.8%)	42.9***
AmbaHudha	Productivity of tree	1	0	3	0	4(3.5%)	4.5^{ns}
Amba Hula	Origin	1	14	0	0	15(13.3%)	57.1***
AmbaKukurfa	Shape of fruit	3	11	0	0	14(12.4%)	36.1***
Amba Lafe	Size of fruit stone	0	3	18	0	21(18.6%)	36.3***
AmbaLibanato	Pulp aroma	0	2	0	0	2(1.8%)	8.0^{ns}
AmbaMaity	Taste of fruit	0	11	0	0	11(9.7%)	47.7***
Amba Mucho	Beak type of the fruit	4	0	0	0	4(3.5%)	16.2***
AmbaNeguse	Fruit size	7	12	26	0	45(39.8%)	38.6***
AmbaSabid	Introduced person	4	0	0	0	4(3.5%)	16.2***
AmbaSabune	Color and texture of fruit	6	0	3	0	9(8%)	15.0***
AmbaSadik	Introduced person	7	0	3	0	10(8.8%)	18.5***
AmbaSeburujena	Origin	0	2	0	0	2(1.8%)	7.9^{ns}
AmbaShimbro	Taste of fruit	1	0	0	0	1(0.9%)	4.0^{ns}
AmbaSibake	Taste of fruit	1	0	0	0	1(0.9%)	4.0^{ns}
AmbaTeyara	Fruit shape	2	0	0	0	2(1.8)	7.9^{ns}
Amba Umar AlishoGuracha	Introduced person	8	0	0	0	8(7.1%)	33.7***
Galbatore	Introduced person	0	0	0	5	5(4.4)	13.8***

[a]*Chi-square* test, ns = not significant,* ,** and *** Significant at $\alpha \leq 0.05$, $\alpha \leq 0.01$, and $\alpha \leq 0.001$, respectively.

Thus, the spacing of the trees was too crowded in some areas and very far apart in other areas. The grower's justifications for irregularity were primarily lack of knowledge and absence of recommended planting spacing. However, regular planting pattern is the most important in realizing good yield and quality of the produce (Verheij, 2006).

Most of the growers did not apply fertilizers to their mangos, though some (36.3%) applied varying amount of organic fertilizers made from compost and manure (Table 5). This is in agreement with Hussen and Yimer (2013) findings who reported 90% of mango growers in northern Ethiopia did not apply fertilizer. The major reasons for excluding inorganic fertilizers were a knowledge gap, cost, and inaccessibility for fertilizers (Table 5). However, proper fertilization program is mandatory in preventing a decline in yield and fruit quality; along with occurrence of imbalance in nutrient status that leads to the biannual bearing phenomenon in mango plant (Shaaban and Shaaban, 2012).

Pruning, bearing behavior of trees and irrigation practices: About half of the growers did not prune their mangos while the few who practiced did it in an irregular and unprofessional manner (Table 6). Consequently, the trees did not have the proper architecture that fit the required pre and post-harvest activities. The observed scenario is in agreement with the mango orchards in

Table 5. Planting pattern and fertilizer application practices of mango grower in the east and western Ethiopia.

Tree management practices	Districts				Total	$\chi 2^a$
	Eastern Ethiopia			Western Ethiopia		
	Erer	Sofi	Babile	Assosa		
Plant spacing:						
Irregular	23	23	36	31	113(100%)	-
Reasons for irregularity:						
Lack of knowledge	20	18	16	25	79(69.9%)	17.8***
No recommended spacing	2	2	9	4	17(15.0%)	
Shortage of land	1	3	11	2	17(15.0%)	
Fertilizer use:						
Organic fertilizer	5	13	23	0	41(36.3%)	35.7***
Do not apply fertilizer	18	10	13	31	72(63.7%)	
Reasons for not applying fertilizer:						
Lack of knowledge	10	10	17	31	68(60.2%)	36.3***
Fertilizers are expensive	13	9	17	0	39(34.5%)	
Inaccessibility of fertilizers	0	4	2	0	6(5.3%)	

[a]*Chi-square* test, ***Significant at $\alpha \leq 0.001$.

Table 6. Pruning, trees bearing behavior and irrigation practices of mango growers in east and western Ethiopia.

Tree management practices	Districts				Total	$\chi 2^a$
	Eastern Ethiopia			Western Ethiopia		
	Erer	Sofi	Babile	Assosa		
Pruning:						
Practice irregularly	10	15	26	5	56(49.6%)	23.9***
Not practicing	13	8	10	26	57(50.4%)	
Reasons for not practicing pruning:						
Lack of knowledge	9	6	11	21	47(41.6%)	19.2**
Lack of skill	9	11	10	2	32(28.3%)	
Fear of losing yield	5	6	15	8	34(30.1%)	
Trees' bearing behavior:						
Irregular/alternate	22	23	34	23	102(90.3%)	13.1**
Regular	1	0	2	8	11(9.7%)	
Regulating bearing of trees:						
Yes	0	8	14	5	27(23.9%)	14.2**
No	23	15	22	26	86(76.1%)	
Irrigation practice:						
Yes but irregularly	8	4	2	0	14(12.4%)	17.1**
No	15	19	34	31	99(87.6%)	
Source of irrigation water:						
Rain	15	19	34	31	99(87.6%)	21.1**
Borehole	7	2	2	0	11(9.7%)	
River	1	2	0	0	3(2.7%)	

[a]*Chi-square* test, ** and *** Significant at $\alpha \leq 0.01$ and $\alpha \leq 0.001$, respectively.

Table 7. Fruit harvesting practices of mango growers in the east and western Ethiopia.

Fruit harvesting practice	Districts				Total	$\chi 2^a$
	Eastern Ethiopia			Western Ethiopia		
	Erer	Sofi	Babile	Assosa		
Harvesting criteria:						
Fruit ripening	23	21	34	31	109(96%)	4.2^{ns}
Market demand	0	2	2	0	4(3.5%)	
Harvesting stage:						
Full ripe	13	7	34	9	63(55.8%)	76.4***
Partially ripe	0	8	2	22	32(28.3%)	
Full and half ripe	10	8	0	0	18(15.9%)	
Harvesting method:						
Hand picking	13	13	36	17	79(69.9%)	22.8***
Using stick	10	10	0	14	34(30.1%)	
Harvesting time:						
Morning	20	14	12	17	63(55.8%)	65.3***
Afternoon	1	8	24	0	33(29.2%)	
Anytime of the day	2	1	0	14	17(15.0%)	

[a]*Chi-square* test, ns = not significant, *** Significant at $\alpha \leq 0.001$.

Northeast Ethiopia (Hussen and Yimer, 2013). The mango tree, however, requires selective pruning of branches to encourage the growth of lateral branches and good tree architecture (Griesbach, 2003). This allows air and sunlight to penetrate, which reduces pests and diseases, and enhances yield and quality of the fruit (Bally, 2011; Nasution, 2013).

The alternate bearing was the common scenario in majority of the respondents' farm. However, most of them did not have any intervention for the alternate bearing, while some growers tried to manage through the application of compost and supplementary irrigation during fruit setting stage of their mangos (Table 6). Alternate bearing is a common challenge for growers in the world that depend on environmental conditions and the genetic makeup of the mango cultivars (Kaur et al., 2014). Moreover, the exhaustion of trees during the period of crop load and vegetative growth at the time of flower differentiation and imbalance in carbon to nitrogen ratio is reported to be among the causes for irregular bearing in mango (Saxena et al., 2014).

Supplementary irrigation was lacking in most farms where the orchards were rainfed (87.6%). However, few growers irrigate their mangos while irrigating their intercrops from their borehole and nearby rivers (Table 6). Proper irrigation is mandatory during critical stages such as flowering, fruiting, and maturity for successful growth and development of mango orchard (Mirjat et al., 2011). Nevertheless, the irrigation amount and frequency is governed by various factors such as the age of the tree, growth stage, climate (humidity, rainfall, and temperature) and soil factors (Mirjat et al., 2011; Sarker and Rahim, 2013)

Harvesting and post-harvest handling practices

Harvesting practices: The harvesting season varies with the location of growers, where it lasts from *March to July* in the west and *May to September* in eastern Ethiopia. Fruit ripening stage was the major criterion for harvesting by most growers, though few consider market demand (Table 7). However, growers did not have scientifically proven fruit maturity standards for harvesting. Thus, most growers harvest fully ripe fruits. While some harvest partially ripe or mixed fruits (Table 7). Mango fruit should be harvested at the right maturity stage; if not, the immature fruit will result in inferior quality while overripe fruits have short postharvest life (Sivakumar et al., 2011; Ahmed and Ahmed, 2014). Therefore, there is a need to determine the appropriate maturity indices of Ethiopian mango based on physical and chemical parameters in order to minimize the quantitative and qualitative losses.

Hand harvesting was the common harvesting method practiced by majorities (Table 7). However, due to lack of proper planting space and canopy management, the trees were too tall and the pickers had to climb on the tree to pick the fruits which were impractical in selecting proper quality fruits to harvest. This poor harvest and handling practices could result in various blemishes on the fruit skin that affect fruit quality and acceptability of

Table 8. Post-harvest and marketing practices of mango growers in the east and western Ethiopia.

Post-harvest and marketing practice	Districts				Total	$\chi 2^a$
	Eastern Ethiopia			Western Ethiopia		
	Erer	Sofi	Babile	Assosa		
Storage type:						
Shade under trees	11	9	28	18	66(58.4%)	10.1**
Storage house	12	14	8	13	47(41.6%)	
Packaging:						
Synthetic fiber sacks	22	23	36	7	88(77.9%)	77.8***
Plastic box (Crates)	0	0	0	9	9(8%)	
Wooden box	1	0	0	3	4(3.5%)	
Do not pack	0	0	0	12	12(10.6%)	
Means of transport:						
Car	12	12	8	24	56(49.6%)	36.0***
Animals (Donkey)	4	2	14	2	22(19.5%)	
Human	1	7	5	5	18(15.9%)	
All of the above	6	2	9	0	17(15%)	
Fruit buyers:						
Retailers	17	21	33	2	73 (64.6%)	69.2***
Wholesalers	6	2	2	19	29(25.7%)	
Processors	0	0	1	10	11(9.7%)	

[a]*Chi-square* test, ** and *** Significant at $\alpha \leq 0.01$ and $\alpha \leq 0.001$, respectively.

the produce by consumers (Mazhar et al., 2011). There were also differences in harvesting time where more than half of the growers harvest in the morning, some in the afternoon and about 15% of growers did not have a time frame for harvest (Table 7). However, harvesting in the morning is the best time to minimize the sap burn injury to the skin of mango (Amin et al., 2008).

Post-harvest handling and marketing: The harvested fruits were mainly stored under mango trees (58.4%) or storehouse (41.6%) constructed from local materials but did not have control facility to regulate environmental variables such as temperature and relative humidity. The storage of matured mango fruit in open air condition and above or below the optimum temperature requirement of the crop shortens the postharvest life and decline of the fruit quality due to rapid softening of the fruits which make the fruits susceptible to handling damages and postharvest pathogen (Emongor, 2015). Therefore, the development of improved mango storage methods that can maintain the fruit quality and enhance its shelf life is mandatory for the growers.

Standard transport and packaging system for the harvested mangos were lacking in the entire studied areas. Accordingly, some growers used motor vehicles, some used animals (donkey) and human to transport their produce to the market. The synthetic fiber sacks were the most common packaging material used and about 10.6% of the growers did not use packaging materials (Table 8). The improper packaging, transport, and inadequate field handling practices require intervention in Ethiopia since they have significant effect postharvest losses, organoleptic, nutritional and functional quality attributes of the fruits (Sivakumar et al., 2011) and marketing costs (Patel et al., 2013). The growers sell their products mainly to retailers followed by wholesalers (Table 8). However, few growers from the western part of Ethiopia sell to cooperative societies who are engaged in processing and value addition.

Major production constraints

Among several constraints reported by the respondents, accessibility to affordable agricultural inputs mainly fertilizers and pesticides were the major bottlenecks followed by pests and diseases. Moreover, knowledge and skill gap about pre and post production practices, poor marketing system, a limited number of improved varieties, flower and fruit drop and biennial bearing behaviors of the mangoes were also among the prioritized challenges (Table 9). The above-stated challenges are similar to those reported from the mango growers located in the northern (Dessalegn et al., 2014)

Table 9. Major mango production constraints in east and western Ethiopia.

Constraints	Districts				Total	$\chi 2^a$
	Eastern Ethiopia			Western Ethiopia		
	Erer	Sofi	Babile	Assosa		
Input	23	23	24	9	79(69.9%)	44.6***
Pest	23	17	32	3	75(66.4%)	65.1***
Knowledge and skill	17	17	3	20	57(50.4%)	38.1***
Market	15	4	15	21	55(48.7%)	16.8***
Commercial cultivars	12	15	5	14	46(40.7%)	18.0***
Flower and fruit drop	9	1	23	0	33(29.2%)	41.7***
Alternate bearing	11	6	12	0	29(25.7%)	17.7***
Land shortage	4	0	7	1	12(10.6%)	8.6*
Drought	2	2	5	0	9(8.0%)	4.44^{ns}
Transportation	2	0	4	0	6(5.3%)	5.96^{ns}

[a]*Chi-square* test, ns = not significant,* and *** Significant at $\alpha \leq 0.05$ and $\alpha \leq 0.01$, respectively.

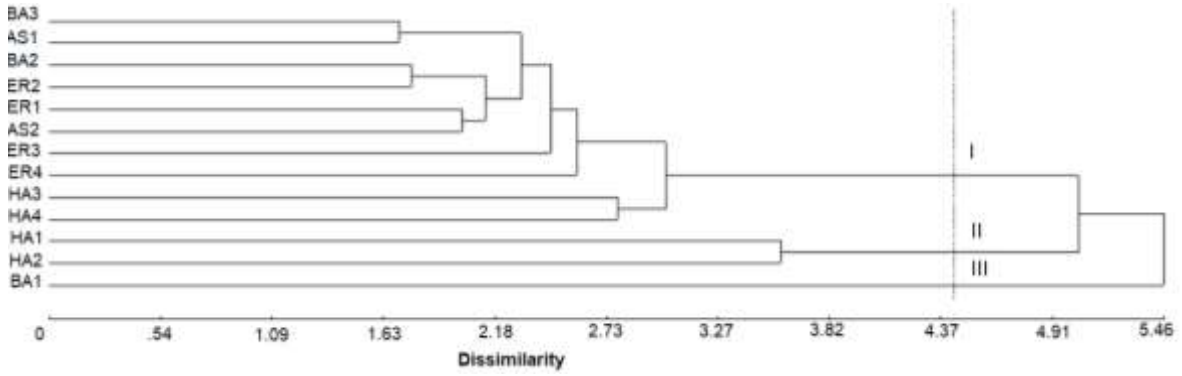

Figure 3. Dendrogram depicting dissimilarity of respondents from east and western Ethiopia.

and North East Ethiopia (Hussen and Yimer, 2013).

Similarity assessment among mango producers

Clustering results revealed respondents in 10 (76.92%) out of 13 villages both from eastern or western parts of the country were grouped under Cluster I. The remaining three villages from eastern Ethiopia were grouped into two clusters of which respondents in AbdibuchMaru (BA1) village from Babile district constructed solitary Cluster III while Nole (HA1) and Agemboy (HA2) from Sofi district constructed Cluster II (Figure 3). This showed that apart from the respondents in three villages, all growers in east and western Ethiopia had similar socioeconomics structure, farming system, mango production experiences and marketing of mangoes. This indicated that there is a possibility to generate packages or strategies on mango production, postharvest and marketing that could be applied in most mango growing regions of the country to enhance the mango sector. It has been suggested that identifying appropriate technologies, preparation of production and postharvest handling packages and providing agriculture extension service for farmers is easier if the farmers have similar socioeconomic situation, production experiences, and problems as compared to diversified situation of producers(Mwangi and Kariuki, 2015; Aremu et al., 2015; Altalb et al., 2015).

CONCLUSION AND RECOMMENDATIONS

The mango sector in Ethiopia is at the infant stage compared to the existing potential. The study revealed that the farmers were practicing mixed cropping system to generate additional income, diversification of their diet, and the majority of them in both east and western part of the country produced mango from the cultivars known by the community traditionally without improved agriculture technologies. It also indicated the existence of high yielding cultivars at farmer's field that needs to be

considered for conservation and improvement strategy. Moreover, unavailability of affordable agricultural inputs, improved varieties, marketing of fruits and low agriculture extension services were the major bottlenecks to the growers in Ethiopia. Therefore, the supply of affordable agricultural inputs and improved varieties, training of growers on technologies of mango production, harvest and postharvest handling is recommended to overcome the production constraints of mango. Safeguarding strategy should be urgently implemented for the identified potential mango cultivars which are on the verge of vanishing. In addition, diversity assessment and characterization of the cultivars is imperative to effectively utilize and/or conserve the genetic resources. However, this study included only the two major production regions (eastern and western Ethiopia) of the country; therefore, it is necessary to extend the similar in-depth research to identify the valuable farmers' mango cultivars, production practices and constraints across the country to alleviate the challenges and move forward the mango sector in Ethiopia.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

We thank Haramaya University (Ethiopia) and DAAD (German academic exchange service) for their financial support. We also grateful to Agriculture Bureau of eastern Hararghe Zone, Oromia Regional State, Harari People's National Regional State and Benishangul Gumuz Regional State, Ethiopia for their cooperation in providing the required informations.

REFERENCES

Ahmed OK, Ahmed SET (2014). Determination of optimum maturity index of mango fruits (*Mangifera indica* L.) in Darfur. Agriculture and Biology Journal of North America 5(2):97-103.

Ahmed THM, Mohamed ZMA (2015). Diversity of Mango (*Mangifera indica* L.) cultivars in Shendi area: morphological fruit characterization. International Journal of Research in Agricultural Sciences 2(4):2348-3997.

Altalb AAT, Filipek T, Skowron P (2015). The Role of agricultural extension in the transfer and adoption of agricultural technologies. Asian Journal of Agriculture and Food Sciences 3(5):500-507.

Amin M, Malik AU, Mazhar MS, Din IU, Khalid MS, Ahmad S (2008). Mango fruit de-sapping in relation to time of harvesting. Pakistan Journal of Botany 40(4):1587-1593.

Aremu PA, Kolo IN, Gana AK, Adelere FA (2015). The crucial role of extension workers in agricultural technologies transfer and adoption. Global Advanced Research Journal of Food Science and Technology 4(2):14-18.

Bally ISE (2011). Advances in research and development of mango industry. Revista Brasileira de Fruticultura 33:57-63.

Begum H, Reddy MT, Malathi S, Reddy BP, Narshimulu G, Nagaraju J, Siddiq EA (2013). Morphological and microsatellite analysis of intravarietal heterogeneity in 'Beneshan' Mango (*Mangifera indica*L.). International Journal of Biotechnology Research and Practice 1(1):1-18.

Berg J. Van Den (2013). Socio-economic factors affecting adoption of improved agricultural practices by small-scale farmers in South Africa. African Journal of Agricultural Research 8(35):4490-4500.

Bisht IS, Mehta PS, Bhandari DC (2007). Traditional crop diversity and its conservation on-farm for sustainable agricultural production in Kumaon Himalaya of Uttaranchal state: a case study. Genetic Resources and Crop Evolution 54:345-357.

Central Statistical Agency (CSA) (2015). Agricultural sample survey time series data for national and regional level. Addis Ababa, Ethiopia. Retrieved from www.csa.gov.et/index.php/26-news/hot-issues.

Dessalegn Y, Assefa H, Derso T, Tefera M (2014). Mango production knowledge and technological gaps of smallholder farmers in Amhara region, Ethiopia. American Scientific Research Journal for Engineering, Technology, and Sciences 10(1):28-39.

Emongor VE (2015). The effects of temperature on storage life of mango (*Mangifera indica* L.). American Journal of Experimental Agriculture 5(3): 252-261. https://doi.org/10.9734/AJEA/2015/12174

Fita T (2014). White mango scale, *Aulacaspis tubercularis*, distribution and severity status in east and west wollega zones, western Ethiopia. Science, Technology and Arts Research Journal 3(3):1-10.

Griesbach J (2003). Mango growing in Kenya. World Agroforestry Center (ICRAF). Nairobi, Kenya.

Hussen S, Yimer Z (2013). Assessment of production potentials and constraints of mango (*Mangifera indica*) at Bati, Oromia zone, Ethiopia. International Journal of Sciences: Basic and Applied Research 11(1):1-9.

IBM Corp. Released (2011). IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.

Jahurul MHA, Zaidul ISM, Ghafoor K, Al-Juhaimi FY, Nyam KL, Norulaini NAN, Mohd Omar AK (2015). Mango (*Mangifera indica* L.) by-products and their valuable components: A review. Food Chemistry 183:173-180.

Kaur M, Bal JS, Bali SK, Sharma LK, Bali SK (2014). An evaluation of mango (*Mangifera indica* L.) germplasm for future breeding programme. African Journal of Agricultural Research 9(20):1530-1538.

Krishna H, Singh SK (2007). Biotechnological advances in mango (*Mangifera indica* L.) and their future implication in crop improvement - A review. Biotechnology Advances 25(3):223-243.

Mazhar MS, Amin M, Malik AU, Campbell J, Johnson P (2011). Improved harvest and de-sapping practices affect mango fruit quality along the supply chains. International Journal of Agriculture and Biology 13:776-780.

Mirjat MS, Jiskani MM, Siyal AA, Mirjat MU (2011). Mango production and fruit quality under properly managed drip irrigation system. Pak. J. Agri., Agril. Engg. Veterinary Sciences 27(1):1-12.

Mwangi M, Kariuki S (2015). Factors determining adoption of new agricultural technology by smallholder farmers in developing countries. Journal of Economic and Sustainable Development 6(5):208-216.

Nasution F (2013). The pruning on mango (*Mangifera indica* L.). ARPN Journal of Agricultural and Biological Science 8(2): 1990-1992.

Ogada M J, Mwabu G, Muchai D (2014). Farm technology adoption in Kenya: a simultaneous estimation of inorganic fertilizer and improved maize variety adoption decisions. Agricultural and Food Economics 2(12):1-18.

Patel P, Singh S, Chavda JC, Patel KA (2013). Effect of grading and packaging with transportation on fruit quality and shelf life of mango fruits. The Asian Journal of Horticulture 8(1):234-237.

Ramette A (2007). Multivariate analyses in microbial ecology. FEMS Microbiology Ecology 62(2):142-160.

Rekhapriyadharshini (2015). A study on the export performance of fresh mangoes from India. International Journal of Interdisciplinary and Multidisciplinary Studies 2(6):134-140.

Rymbai H, Laxman RH, Dinesh MR, Sunoj VSJ, Ravishankar KV, Jha AK (2014). Diversity in leaf morphology and physiological characteristics among mango (*Mangifera indica*) cultivars popular in different agro-climatic regions of India. Scientia Horticulturae

176:189-193.
Sarker BC, Rahim MA (2013). *Mangifera indica*. Bangladesh Journal of Agricultural Research 38(1): 145-154.
Saxena P, Singh VK, Pathak N (2014). Antioxidative enzymes and biochemical changes in paclobutrazol induced flowering in mango (*M. indica*) cultivars. Journal of Enviromental Biology 35:1061-1066.
Sivakumar D, Jiang Y, Yahia EM (2011). Maintaining mango (*Mangifera indica* L.) fruit quality during the export chain. Food Research International 44:1254-1263.
Sneath PHA, Sokal RR (1973). Numerical taxonomy. The principles and practice of numerical classification. (D. Kennedy and R. B. Park, Eds.). W.H. Freeman and Company. San Francisco. Retrieved from http://www.jstor.org/stable/2412767?origin=crossref
Swain SC (2014). Performance and profitability study of different mango based intercropping systems in Eastern Ghat high land zone of Odisha. Journal of Crop and Weed 10(2):170-178.
Tiwari R, Baghel BS (2014). Effect of intercropping on plant and soil of Dashehari mango orchard under low productive environments. Asian Journal of Horticulture 9(2):439-442.
Ullah H, Saeed A, Thompson AK, Ahmad W, Azher Nawaz M (2010). Storage of ripe mango (*Mangifera indica* L.) cv. alphonso in controlled atmosphere with elevated CO_2. Pakistan Journal of Botany 42(3):2077-2084.
Vasugi C, Dinesh MR, Sekar K, Shivashankara KS, Padmakar B, Ravishankar KV (2012). Genetic diversity in unique indigenous mango accessions (Appemidi) of the Western Ghats for certain fruit characteristics. Current Science 103(2):199-207. https://doi.org/10.1007/s13592-011-0065-1.24.
Verheij E (2006). Fruit growing in the tropics (Third). Digigrafi, Wageningen, the Netherlands: Agromisa Foundation and CTA, Wageningen.
Xiahong HE, Yan SUN, Dong GAO, Fugang WEI, Lei PAN, Cunwu GUO, Youyong ZHU (2011). Comparison of agronomic traits between rice landraces and modern varieties at different altitudes in the paddy fields of Yuanyang terrace, Yunnan province. Journal of Resources and Ecology 2(1):46-50.
Yong'an L, Quanwen D, Zhiguo C, Deyong Z (2010). Effect of drought on water use efficiency, agronomic traits and yield of spring wheat landraces and modern varieties in Northwest China. African Journal of Agricultural Research 5(13):1598-1608.
Sennhenn A, Prinz K, Gebauer J, Whitbread A, Jamnadass R, Kehlenbeck K (2013). Identification of mango (*Mangifera indica* L.) landraces from Eastern and Central Kenya using a morphological and molecular approach. Genetic Resources and Crop Evolution 61(1): 7-22.
Shaaban SHA, Shaaban MM (2012). Impact of the nutritional status on Yield of nine mango cultivars grown under farm conditions at Giza Governorate, Egypt. Journal of American Science 8(5):304-310.
Shi S, Ma X, Xu W, Zhou Y, Wu H, Wang S (2015). Evaluation of 28 mango genotypes for physicochemical characters, antioxidant capacity, and mineral content. Journal of Applied Botany and Food Quality 88:264-273.