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

Tewodros B. Neguse1*, Fredah K. R. Wanzala2, Wassu M. Ali1, Willis O. Owino3 and Githiri S. Mwangi2

1School of Plant Sciences, Haramaya University, Haramaya, Ethiopia.
2Department of Horticulture, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya.
3Department of Food Science and Technology, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya.

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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
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).
DATA WERE COLLECTED THROUGH INDIVIDUAL FARMERS’ INTERVIEWS USING THE QUESTIONNAIRE AND REMEDIAL ACTION WAS MADE ACCORDINGLY. DIFFERENCES AMONG THE DISTRICTS WHERE THE GROWERS WERE LOCATED. THE OVERALL THROUGH FIELD OBSERVATION. IT INCLUDED SOCIO-ECONOMICS, EXISTING FARMERS’ CULTIVARS, 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.

**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 were 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 Wollega 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 trees per household. 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 were 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).

**Table 1. Details of selected villages and districts.**

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Eastern Ethiopia</th>
<th>Western Ethiopia</th>
<th>Total</th>
<th>( \chi^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-40</td>
<td>11.0</td>
<td>12.0</td>
<td>2.0</td>
<td>47(41.6%)</td>
</tr>
<tr>
<td>41-50</td>
<td>8.0</td>
<td>8.0</td>
<td>10.0</td>
<td>33(29.2%)</td>
</tr>
<tr>
<td>&gt;50</td>
<td>4.0</td>
<td>3.0</td>
<td>4.0</td>
<td>22.0</td>
</tr>
<tr>
<td>Mean</td>
<td>43.7</td>
<td>41.4</td>
<td>40.1</td>
<td>55.8</td>
</tr>
</tbody>
</table>

Education level:

<table>
<thead>
<tr>
<th></th>
<th>Eastern Ethiopia</th>
<th>Western Ethiopia</th>
<th>Total</th>
<th>( \chi^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>No school</td>
<td>16.0</td>
<td>14.0</td>
<td>18.0</td>
<td>9.0</td>
</tr>
<tr>
<td>Primary school</td>
<td>5.0</td>
<td>8.0</td>
<td>18.0</td>
<td>22.0</td>
</tr>
<tr>
<td>Secondary school</td>
<td>2.0</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Eastern Ethiopia</th>
<th>Western Ethiopia</th>
<th>Total</th>
<th>( \chi^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mango trees per farm:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;15</td>
<td>10</td>
<td>9</td>
<td>23</td>
<td>16</td>
</tr>
<tr>
<td>15-30</td>
<td>10</td>
<td>8</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>&gt;30</td>
<td>3</td>
<td>6</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Mean</td>
<td>20.0</td>
<td>23.1</td>
<td>13.2</td>
<td>32.1</td>
</tr>
<tr>
<td>Farming experience in years:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;15</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>15-30</td>
<td>14</td>
<td>14</td>
<td>26</td>
<td>16</td>
</tr>
<tr>
<td>&gt;30</td>
<td>3</td>
<td>6</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Mean</td>
<td>27.5</td>
<td>27.5</td>
<td>25.2</td>
<td>34.2</td>
</tr>
<tr>
<td>Cultivation knowledge source:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ancestors/family</td>
<td>23</td>
<td>19</td>
<td>25</td>
<td>19</td>
</tr>
<tr>
<td>Neighbor’s</td>
<td>0</td>
<td>4</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Extension agents</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Reasons for cultivation:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Best money making</td>
<td>19</td>
<td>22</td>
<td>29</td>
<td>20</td>
</tr>
<tr>
<td>Tradition</td>
<td>4</td>
<td>1</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>No alternatives</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Planting material:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seed</td>
<td>23</td>
<td>23</td>
<td>36</td>
<td>31</td>
</tr>
<tr>
<td>Mixed</td>
<td>23</td>
<td>23</td>
<td>36</td>
<td>31</td>
</tr>
</tbody>
</table>

*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...
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 use 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; Tiwari and 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).
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

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

<table>
<thead>
<tr>
<th>Cultivars name</th>
<th>Meaning and basis for naming in the local language</th>
<th>Eastern Ethiopia</th>
<th>Western Ethiopia</th>
<th>Total</th>
<th>( \chi^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Erer</td>
<td>Sofi</td>
<td>Babile</td>
<td>Assosa</td>
</tr>
<tr>
<td>Almenga</td>
<td>Meaning mango</td>
<td>0</td>
<td>0</td>
<td>31</td>
<td>31(27.4%)</td>
</tr>
<tr>
<td>Amba Adi</td>
<td>Fruit color</td>
<td>14</td>
<td>7</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>Amba Ako</td>
<td>Name of introduced person</td>
<td>10</td>
<td>1</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Amba Arenajeta</td>
<td>Texture and taste of fruit</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amba Bere</td>
<td>Name of introduced person</td>
<td>15</td>
<td>7</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>Amba Bishaano</td>
<td>Taste and juiciness of fruit</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amba Dada</td>
<td>Fruit flush texture when ripe</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amba Demma</td>
<td>Taste of fruit</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amba Dula</td>
<td>Introduced person</td>
<td>0</td>
<td>0</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>Amba Errero</td>
<td>Origin</td>
<td>0</td>
<td>16</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amba Fulla</td>
<td>Shape of the fruit</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Amba Gerjewi</td>
<td>Taste and texture of fruit</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amba Guracha</td>
<td>Color of fruit skin when ripe</td>
<td>17</td>
<td>4</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>Amba Harewe</td>
<td>Origin</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amba Hudha</td>
<td>Productivity of tree</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Amba Hula</td>
<td>Origin</td>
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<td>14</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amba Kukurma</td>
<td>Shape of fruit</td>
<td>3</td>
<td>11</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amba Lafa</td>
<td>Size of fruit stone</td>
<td>0</td>
<td>3</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>Amba Libanato</td>
<td>Pulp aroma</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amba Maity</td>
<td>Taste of fruit</td>
<td>0</td>
<td>11</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amba Mucho</td>
<td>Beak type of the fruit</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amba Neguse</td>
<td>Fruit size</td>
<td>7</td>
<td>12</td>
<td>26</td>
<td>0</td>
</tr>
<tr>
<td>Amba Sabid</td>
<td>Introduced person</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amba Sabune</td>
<td>Color and texture of fruit</td>
<td>6</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Amba Sadik</td>
<td>Introduced person</td>
<td>7</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Amba Seburujena</td>
<td>Origin</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amba Shimbro</td>
<td>Taste of fruit</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amba Sibake</td>
<td>Taste of fruit</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amba Teyara</td>
<td>Fruit shape</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amba Ulmar</td>
<td>Introduced person</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Galbatore</td>
<td>Introduced person</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
</tbody>
</table>

*Chi-square test, ns = not significant, *, ** and *** Significant at \( \alpha \leq 0.05 \), \( \alpha \leq 0.01 \), and \( \alpha \leq 0.001 \), respectively.
Table 5. Planting pattern and fertilizer application practices of mango grower in the east and western Ethiopia.

<table>
<thead>
<tr>
<th>Tree management practices</th>
<th>Eastern Ethiopia</th>
<th>Western Ethiopia</th>
<th>Total</th>
<th>$\chi^2$\textsuperscript{a}</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Erer</td>
<td>Sofi</td>
<td>Babile</td>
<td>Assosa</td>
</tr>
<tr>
<td>Plant spacing:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irregular</td>
<td>23</td>
<td>23</td>
<td>36</td>
<td>31</td>
</tr>
<tr>
<td>Reasons for irregularity:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of knowledge</td>
<td>20</td>
<td>18</td>
<td>16</td>
<td>25</td>
</tr>
<tr>
<td>No recommended spacing</td>
<td>2</td>
<td>2</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>Shortage of land</td>
<td>1</td>
<td>3</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Fertilizer use:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic fertilizer</td>
<td>5</td>
<td>13</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>Do not apply fertilizer</td>
<td>18</td>
<td>10</td>
<td>13</td>
<td>31</td>
</tr>
<tr>
<td>Reasons for not applying fertilizer:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of knowledge</td>
<td>10</td>
<td>10</td>
<td>17</td>
<td>31</td>
</tr>
<tr>
<td>Fertilizers are expensive</td>
<td>13</td>
<td>9</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>Inaccessibility of fertilizers</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

\textsuperscript{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.

<table>
<thead>
<tr>
<th>Tree management practices</th>
<th>Eastern Ethiopia</th>
<th>Western Ethiopia</th>
<th>Total</th>
<th>$\chi^2$\textsuperscript{a}</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Erer</td>
<td>Sofi</td>
<td>Babile</td>
<td>Assosa</td>
</tr>
<tr>
<td>Pruning:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Practice irregularly</td>
<td>10</td>
<td>15</td>
<td>26</td>
<td>5</td>
</tr>
<tr>
<td>Not practicing</td>
<td>13</td>
<td>8</td>
<td>10</td>
<td>26</td>
</tr>
<tr>
<td>Reasons for not practicing pruning:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of knowledge</td>
<td>9</td>
<td>6</td>
<td>11</td>
<td>21</td>
</tr>
<tr>
<td>Lack of skill</td>
<td>9</td>
<td>11</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Fear of losing yield</td>
<td>5</td>
<td>6</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>Trees’ bearing behavior:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irregular/alternate</td>
<td>22</td>
<td>23</td>
<td>34</td>
<td>23</td>
</tr>
<tr>
<td>Regular</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Regulating bearing of trees:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>0</td>
<td>8</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>No</td>
<td>23</td>
<td>15</td>
<td>22</td>
<td>26</td>
</tr>
<tr>
<td>Irrigation practice:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes but irregularly</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>No</td>
<td>15</td>
<td>19</td>
<td>34</td>
<td>31</td>
</tr>
<tr>
<td>Source of irrigation water:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rain</td>
<td>15</td>
<td>19</td>
<td>34</td>
<td>31</td>
</tr>
<tr>
<td>Borehole</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>River</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

\textsuperscript{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.

<table>
<thead>
<tr>
<th>Fruit harvesting practice</th>
<th>Eastern Ethiopia</th>
<th>Western Ethiopia</th>
<th>Total</th>
<th>$\chi^2$a</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Erer</td>
<td>Sofi</td>
<td>Babile</td>
<td>Assosa</td>
</tr>
<tr>
<td>Harvesting criteria:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruit ripening</td>
<td>23</td>
<td>21</td>
<td>34</td>
<td>31</td>
</tr>
<tr>
<td>Market demand</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Harvesting stage:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full ripe</td>
<td>13</td>
<td>7</td>
<td>34</td>
<td>9</td>
</tr>
<tr>
<td>Partially ripe</td>
<td>0</td>
<td>8</td>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td>Full and half ripe</td>
<td>10</td>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Harvesting method:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand picking</td>
<td>13</td>
<td>13</td>
<td>36</td>
<td>17</td>
</tr>
<tr>
<td>Using stick</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>Harvesting time:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morning</td>
<td>20</td>
<td>14</td>
<td>12</td>
<td>17</td>
</tr>
<tr>
<td>Afternoon</td>
<td>1</td>
<td>8</td>
<td>24</td>
<td>0</td>
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<tr>
<td>Anytime of the day</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>14</td>
</tr>
</tbody>
</table>

*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
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.

<table>
<thead>
<tr>
<th>Constraints</th>
<th>Eastern Ethiopia</th>
<th>Western Ethiopia</th>
<th>Total</th>
<th>χ²a</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Erer</td>
<td>Sofi</td>
<td>Babile</td>
<td>Assosa</td>
</tr>
<tr>
<td>Input</td>
<td>23</td>
<td>23</td>
<td>24</td>
<td>9</td>
</tr>
<tr>
<td>Pest</td>
<td>23</td>
<td>17</td>
<td>32</td>
<td>3</td>
</tr>
<tr>
<td>Knowledge and skill</td>
<td>17</td>
<td>17</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>Market</td>
<td>15</td>
<td>4</td>
<td>15</td>
<td>21</td>
</tr>
<tr>
<td>Commercial cultivars</td>
<td>12</td>
<td>15</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>Flower and fruit drop</td>
<td>9</td>
<td>1</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>Alternate bearing</td>
<td>11</td>
<td>6</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>Land shortage</td>
<td>4</td>
<td>0</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Drought</td>
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<td>2</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Transportation</td>
<td>2</td>
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<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

*aChi-square test, ns = not significant,* and *** Significant at α ≤ 0.05 and α ≤ 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.

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