academicresearchJournals

Vol. 5(7), pp. 561-569, November 2017
DOI: 10.14662/ARJASR2017.087

ISSN: 2360-7874
http://www.academicresearchjournals.org/ARJASR/Index.htm

**Academic Research Journal of Agricultural Science and Research**

***Full Length Research***

# Development of Hermaphrodite Papaya (*Carica papaya* L.) Varieties for Production in Ethiopia

**Lemma Ayele*[1], Edossa Etissa[1], Asmare Dagnew[1], Wagayehu Assefa[1], Girma Kebede[1], Mekasha Girma[2], Kidist Firde[3], and Merkedu Ayalew[1]**

[1]Melkassa Agricultural Research Center, P.O.Box 436, Adama, Ethiopia
[2]Werer Agricultural Research Center, P.O.Box 2003, Werer, Ethiopia
[3]Holetta Agricultural Research Center, P.O.Box 6282, Holetta, Ethiopia.
**Corresponding author's e-mail: lemmaayeleb@gmail.com*

Accepted 29 November 2017

**Papaya (*Carica papaya* L.) is an important tropical fruit with many nutritional, medicinal and economic values. Despite of great potential to produce papaya and high demand of growers for improved papaya varieties, no any variety was released or registered in Ethiopia. Trials were conducted to develop and release high yielding and quality hermaphrodite papaya varieties in the country. Nine good performing hermaphrodite varieties were selected from developed pure lines for variety trial. The selected varieties were CMF078-L56, KK103-L459, CMF021-L77, KK103-L446, Lowbearing-L36, CMF021-L74, CMF019-L79, CMF008-L94 and MK121-L516. The varieties were observed in four locations. The trial was laid in Randomized Complete Block Design with three replications. Three year data at Melkassa Agricultural Research Center was subjected to analysis with SAS computer software; and their qualitative performance were analyzed to identify outstanding varieties for verification trial. The variety release technical committee has evaluated proposed hermaphrodite varieties for verification; and three varieties such as CMF078-L56, KK103-L446 and MK121-L516 were released, from respective fruit size categories (small, medium and large), as first success in history of papaya research in Ethiopia. Respective names or designations given to these varieties were Braz-HS1, Koka-HM1 and Meki-HL1. Their productivities were 64.7, 75.2 and 87.3 t/ha; and they showed 176.9%, 221.8% and 273.6% yield advantage as compared to national average (23.37 t/ha), respectively. Therefore, the three hermaphrodite papaya varieties have recommended to be produced in central rift valley and similar agro-ecologies of the country.**

**Key words:** Hermaphrodite papaya, variety development, fruit size category, released varieties

**Cite this article as**: Ayele L, Etissa E, Dagnew A, Assefa W, Kebede G, Girma M, Firde K, Ayalew M (2017). Development of Hermaphrodite Papaya (*Carica papaya* L.) Varieties for Production in Ethiopia. Acad. Res. J. Agri. Sci. Res. 5(7): 561-569

## INTRODUCTION

Papaya (*Carica papaya* L.) is native to tropical America and popular fruit in many tropical countries. It is a herbaceous perennial grown for its small to large melon-like fruit, that bear fruit at the leaf axils spirally arranged along the single erect trunk (Paull and Duarte, 2011). It gives yield year round regardless of season as long as they get optimum agronomic managements. There are two types; dioecious and hermaphrodites. In dioecious

types male and female flowers or inflorescences are born on different plants; whereas both flowers found on the single tree in hermaphrodites or bisexual (Agrawal, 2002).

The papaya is an attractive and delicious tropical fruits with many nutritional and medicinal properties. The fruit contains 85% water, 10-13% sugar, 0.6% protein, much of vitamin A and fair amount of B1,B2 and C (Samson, 1986). The ripe fruit may be consumed fresh, use to for extraction of papain (use as meat tenderizer) and /or the green fruit is used by health and cosmetic industries amongst it may uses. It could be used as raw materials for soft drinks, jams and various preserves. The food canning industries could also use ripe fruits as filler in the manufacture of many products (Josef, 2008).

Papaya has been cultivated in several countries for local consumption and export market. About sixty countries are producing papaya from which most of them are from developing countries. World papaya production was estimated 11.22 million metric tons in 2010. Production in 2010 was 7.26 percent higher than the previous year and 63.67 percent above the 2000 crop. Asia is the top papaya producing continent, with about 52.55% of the world production during the 2008 to 2010 period, followed by South America (23.09%) and Africa (13.16%) (FAOSTAT 2012).

Ethiopia is among five top papaya producing country in Africa (https://www.mapsofworld.com). Based on CSA 2015, papaya ranks the third in amount of fruit production (40,435.06 tons) during 2014/15 cropping season with area coverage of 3,109.52 hectares. Papaya is being produced in all regional states of Ethiopia and consumed as fresh fruit in most parts of the country. About 15, 572,313 Ethiopian small holder farmers were involved in papaya production. Area of papaya production increased from 22,262.52 to 40,435.06 hectares from year 2011 to 2015 which is 81.6% total increment within five years interval.

Papaya is extremely cross pollinated crop and it is difficult to get pure seeds by open pollination; hence uncontrolled seed propagation soon leads to inferior types. Therefore, hand controlled pollination is required for both dioecious and bisexual or hermaphrodite cultivars (Samson, 1986). To develop elite papaya lines, continuous selfing for hermaphrodite papaya materials and mating of siblings (sib-pollination) for dioecious materials through Single-Tree-Descent Selection Method is required (Paull and Duarte, 2011).

Many dioecious and hermaphrodite papaya accessions had been collected locally and introduced from abroad few decades back. In order to get true-to-type, purification of these materials was started through controlled pollinations (MARC, 2004). In developing papaya lines (varieties) continuous controlled Single–Tree-Descent-Selection Method was used from the original population (Agrawal, 2002).

Despite of great potential to produce papaya and high demand of growers (farmers and investors) for improved papaya varieties, no any variety was released or registered in the country. Some years back a variety trial was conducted to evaluate and select high yielding and quality papaya lines. Fortunately, outstanding hermaphrodite papaya lines which have tested in several papaya growing areas of Ethiopia were verified and officially released for production in the year 2015. Thus, the objective of the trials was to develop and release high yielding and quality hermaphrodite papaya varieties in Ethiopia for different purposes; and to introduce and describe released varieties.

## MATERIALS AND METHODS

### Pure line development and variety trial

Forty three hermaphrodite papaya accessions have been maintained through manual controlled pollination. Most of the materials were collected from central valley of Ethiopia and some were introduced from different countries. The materials were categorized in to small, medium, large and extra large groups based on fruit size. Controlled pollination was performed in such a way that flowers were covered by paper bags, just before opening, to induce self pollination and protect pollen from other sources. They were labeled to distinguish them from open pollinated ones (Nakasone and Paull, 1998).

When papaya pure line development reached sixth generation, nine good performing hermaphrodite varieties were selected for multilocational variety trial. They were planted in four locations such as Melkassa, Werer, Ziway and Tibilla. The RCBD design with three replication was used. The varieties were observed for their performance and had performed well in all locations. However, three year data from Melkassa site was used to select outstanding varieties and four varieties were selected for next verification trial.

### Variety verification trial

Four hermaphrodite papaya varieties from three categories (small, medium and large) were selected and planted in single plot for verification. No standard check was used since there was no any papaya variety released so far. Request for evaluation and verification was submitted to Plant Variety Release, Protection and Seed Quality Control Directorate under Ministry of Agriculture. The assigned variety release technical committee had visited the trials for field evaluation during fruiting season.

### Description of study areas

Many controlled and introduced papaya materials were maintained and pure line development activities have been practiced at Melkassa Agricultural Research Center. The national variety trial for selected varieties was conducted in four locations such as Melkassa, Tibilla, Werer and Ziway. While verification trial was planted at six location such as Alem Tena, Bisholla, Melkassa, Waketiyo, Wenji, Werer and Ziway. All study areas are situated in Rift Valley areas in Ethiopia. These are lowland areas with moderate to high temperature of average 25-32$^{o}$C. The altitude for these locations ranged from about 700 to 1700m. They characterized by low to moderate moisture stress area.

### Agronomic practices

Papaya seedlings had raised from pure seed which was produced through controlled pollination. All recommended agronomic practices were applied uniformly to all varieties. Spacing used both between plants and rows was 2.5m. During dry period irrigation was applied through furrow method; and its interval was ranged from 3 to 10 days depending on whether and growth stage.

## RESULT AND DISCUSSION

### Performance of Selected Papaya Varieties

### Fruit yield

The papaya varieties were showed significant different for their fruit yields during the first year but the differences were non-significant during the second and the third years (Appendix table 1). This may indicate that tested varieties differ to start fruit; once they start fruiting they would continuously harvested every week provided that optimum cultural managements and irrigation watering are given.

During first year the highest yield were gained for MK121-L#516 (66.79 t/ha) followed by KK103-L446 (38.15); and the least yield were for Low bearing-L36 and KK103-L459 (Table 3). Generally yield during first year was very low as compared to that of second and third year; mean yield for second and third year showed 190% and 178% higher increment than mean yield of first year. This could be because papaya started to bear fruits after eight to 10 months from planting and during that time it shows only vegetative growth.

The highest yields in second and third year were attained by MK121, L#516 (118.25 tons) and CMF021-L74 (105.93 tons), respectively. Maximum and minimum fruit yields were 87.30 and 61.09 tons for MK121-L516 and KK103-L459. These yields have 273.6% to 161.5% yield advantages as compared to national average. Their yield performances differ non-significantly in second and third year; and this revealed that after first year all tested varieties showed comparable potential with regards to fruit yields. However, the varieties further observed for their qualitative parameters to generate supportive information to select outstanding varieties.

### Fruit weight

Analysis of variance showed that papaya varieties were significantly different for fruit weight throughout three years (Appendix table 2). Papaya variety with largest average fruit weight was MK121-L516 (923.0 grams) followed by CMF008-L94 (957.6 grams). The varieties with small average fruit weight were CMF021-L77, KK103-L459 and CMF078-L56 (Table 4). This indicates that the varieties fall in different fruit categories based on their fruit size; and they can be recommended for different purposes.

### Quality parameters

High yield is not the only objective of papaya breeding; varieties should show good quality performance with regard to sweetness, fruit shape, flesh color and etc (Josef, 2008). Therefore, it is not wise decision to select a variety based on yield performance only. But quality attributes should be taken into account. Based on information presented in Table 5, all varieties performed well for several parameters among quality parameters considered. All tested varieties were with low amount of fiber content in their flesh parts. All varieties had low ridging of fruit surface except CMF008-L94 that showed medium ridging. The varieties CMF021-L74 and CMF019-L79 showed elongated fruit shape and yellow flesh color which are less desirable fruit quality. Yellowish flesh color may indicate less Vitamin A content; whereas redish flesh color is preferable since it is related with higher Vitamin A content. Four top varieties with regard to total soluble solutes (TSS in $^{o}$Brix) were MK121-L516 (14.1), KK103-L459 (12.9), KK103-L446 (13.6) and CMF078-L56 (11.84); while CMF021-L74 was with the least TSS value.

### Selection of outstanding varieties

Based on yield and quality performance four hermaphrodite varieties (CMF078-L56, CMF021-L77, KK103-L446 and MK121-L516) were selected and planted in different locations for verification. During fruiting season Variety Release Technical Committee had visited the trials for field evaluation. Three hermaphrodite papaya varieties (one from each category) were selected by the Technical Committee for their outstanding

**Table 1.** Papaya varieties selected for multilocational variety trial

| No | Varieties | Fruit size category |
|---|---|---|
| 1 | CMF078-L56 | Small |
| 2 | KK103-L459 | Small |
| 3 | CMF021-L77 | Small |
| 4 | KK103-L446 | Medium |
| 5 | Low bearing-L36 | Medium |
| 6 | CMF021-L74 | Medium |
| 7 | CMF019-L79 | Large |
| 8 | CMF008-L94 | Large |
| 9 | MK121-L516 | Large |

**Table 2.** Brief description of the study areas

| No | Locations | Altitude | Geographic Coordinates | Average Temprature | | Annual rainfall |
|---|---|---|---|---|---|---|
| | | | | Minimum | Maximum | |
| 1 | Melkassa | 1550m | 8°24'N; 39°21'E | 14°C | 28.4°C | 763 mm |
| 2 | Tibilla | 1200m | 9°01'N; 38.44'E | 19.7°C | 32.0°C | 520 mm |
| 3 | Werer | 750m | 9°16'N; 40°9'E | 26.8°C | 40.8°C | 590 mm |
| 4 | Ziway | 1643m | 7°56'N; 38°43'E | 12.5°C | 26.2°C | 775 mm |

**Table 3.** Yield performance of papaya varieties (t/ha)

| No | Variety | TY1 | TY2 | TY3 | Mean |
|---|---|---|---|---|---|
| 1 | MK121-L516 | 66.79$^{a}$ | 118.25 | 76.87 | 87.30$^{a}$ |
| 2 | KK103-L446 | 38.15$^{b}$ | 90.59 | 96.86 | 75.20$^{bc}$ |
| 3 | CMF008-L94 | 34.48$^{bc}$ | 89.73 | 92.78 | 72.33$^{b}$ |
| 4 | CMF021-L74 | 31.23$^{bcd}$ | 105.80 | 105.93 | 80.99$^{ab}$ |
| 5 | CMF021-L77 | 29.21$^{bcd}$ | 102.40 | 99.02 | 76.88$^{bc}$ |
| 6 | CMF078-L56 | 25.41$^{cd}$ | 87.71 | 80.98 | 64.70$^{c}$ |
| 7 | CMF019-L79 | 22.40$^{d}$ | 77.64 | 86.22 | 62.09$^{bc}$ |
| 8 | KK103-L459 | 21.09$^{d}$ | 79.07 | 83.12 | 61.09$^{c}$ |
| 9 | Low bearing-L36 | 21.08$^{d}$ | 89.94 | 83.10 | 64.71$^{bc}$ |
| | Mean | 32.20 | 93.46 | 89.43 | 71.70 |
| | P-value | <0.0001 | 0.1273 | 0.1681 | 0.0064 |
| | LSD | 112.2 | 283.4 | 221.0 | 146.9 |
| | CV | 20.2 | 17.5 | 14.3 | 12.8 |

Where: TY1=Total fruit yield during first year; TY2=Total fruit yield during second year; TY3=Total fruit yield during third year

**Table 4.** Average fruit weight of papaya varieties (g)

| No | Variety | FW1 | FW2 | FW3 | Mean |
|---|---|---|---|---|---|
| 1 | MK121-L516 | 592.8$^{bcd}$ | 1107.3$^{a}$ | 1068.9$^{a}$ | 923.0$^{a}$ |
| 2 | CMF019-L79 | 769.2$^{a}$ | 944.7$^{b}$ | 764.9$^{b}$ | 826.3$^{b}$ |
| 3 | CMF008-L94 | 745.2$^{ab}$ | 1047.6$^{ab}$ | 1080.0$^{a}$ | 957.6$^{a}$ |
| 4 | CMF021-L74 | 673.3$^{ab}$ | 711.9$^{cd}$ | 582.4$^{c}$ | 655.9$^{c}$ |
| 5 | KK103-L446 | 548.2$^{cde}$ | 579.3$^{de}$ | 549.4$^{c}$ | 559.0$^{d}$ |
| 6 | CMF021-L77 | 484.7$^{def}$ | 555.6$^{e}$ | 489.3$^{c}$ | 509.9$^{e}$ |
| 7 | CMF078-L56 | 412.1$^{ef}$ | 429.0$^{e}$ | 454.9$^{c}$ | 432.0$^{e}$ |
| 8 | Low bearing-L36 | 383.3$^{ef}$ | 753.7$^{c}$ | 501.3$^{c}$ | 546.1$^{de}$ |
| 9 | KK103-L459 | 329.0$^{f}$ | 566.6$^{de}$ | 441.7$^{c}$ | 445.8$^{e}$ |
| | P-value | 0.0002 | <0.0001 | <0.0001 | <0.0001 |
| | LSD | 168.9 | 149.4 | 152.8 | 92.7 |
| | CV | 17.8 | 11.4 | 13.4 | 10.4 |

Where: FW1=Average fruit weight per fruit during first year; FW2= Average fruit weight per fruit during second year; FW3= Average fruit weight per fruit during third year

**Table 5**: Performance of selected papaya varieties with regard to qualitative parameters

| No. | Variety | TSS | Ridging of fruit surface | Shape of central cavity | Central cavity diameter | Flesh fiber (0/+) | Smoothness | Flesh color | Fruit shape |
|---|---|---|---|---|---|---|---|---|---|
| 1 | CMF078-L56 | 11.84 | Low | star shape | 4.03 | 0 | rough | redish | pear |
| 2 | KK103-L446 | 13.6 | Low | star shape | 3.95 | 0 | intermediate | deep redish | pear |
| 3 | KK103-L459 | 12.9 | Low | Zigzag | 3.64 | 0 | intermediate | redish | pear |
| 4 | CMF021- L77 | 6.88 | Low | irregular zigzag | 4.20 | 0 | rough | light yellow | pear |
| 5 | Low bearing-L36 | 8.38 | Low | zigzag | 3.12 | 0 | intermediate | light yellow | pear |
| 6 | CMF021-L74 | 6.15 | Low | irregular zigzag | 3.67 | 0 | rough | yellow | Elongated |
| 7 | CMF019-L79 | 9.34 | Low | Star shape | 3.40 | 0 | intermediate | yellow | Elongated |
| 8 | CMF008-L94 | 8.33 | Medium | Star shape | 4.36 | 0 | intermediate | redish | Pear |
| 9 | MK121, L516 | 14.1 | Low | Star shape | 4.01 | 0 | intermediate | redish | Pear |

performances. Upon suggestion of the committee these varieties were officially approved in the year 2015 by National Variety Releasing Committee to be released for wide production in the country (MoA, 2015). The hermaphrodite varieties such as CMF078-L56, KK103-L446 and MK121-L516 were approved for release from small, medium and large fruit categories, respectively.

**Designations given for released varieties**

After the approval of the varieties, tropical fruit team (researchers) at Melkassa Agricultural Research Center have discussed to designate appropriate names. The three released papaya varieties have given local designations (names) as follows:

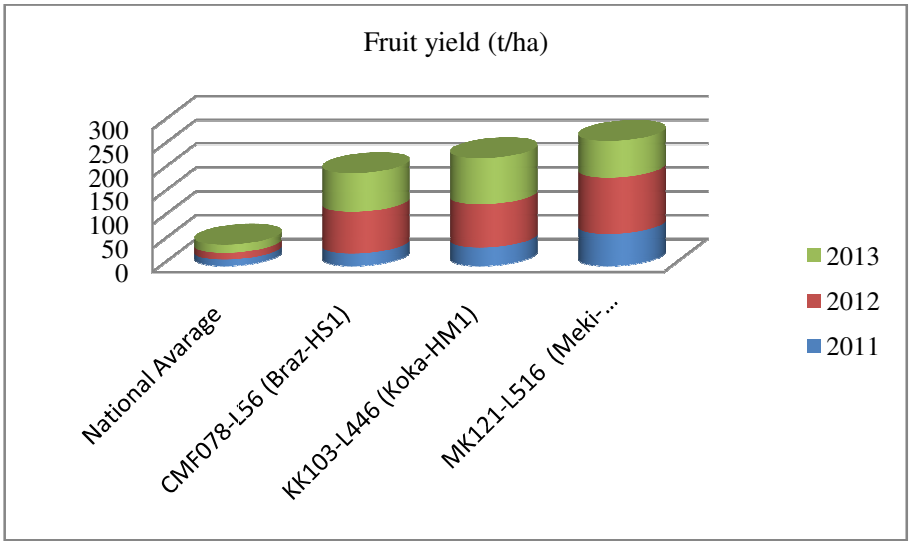


**Figure 1**. Total fruit yield of three released varieties harvested in three years (2011-2013)

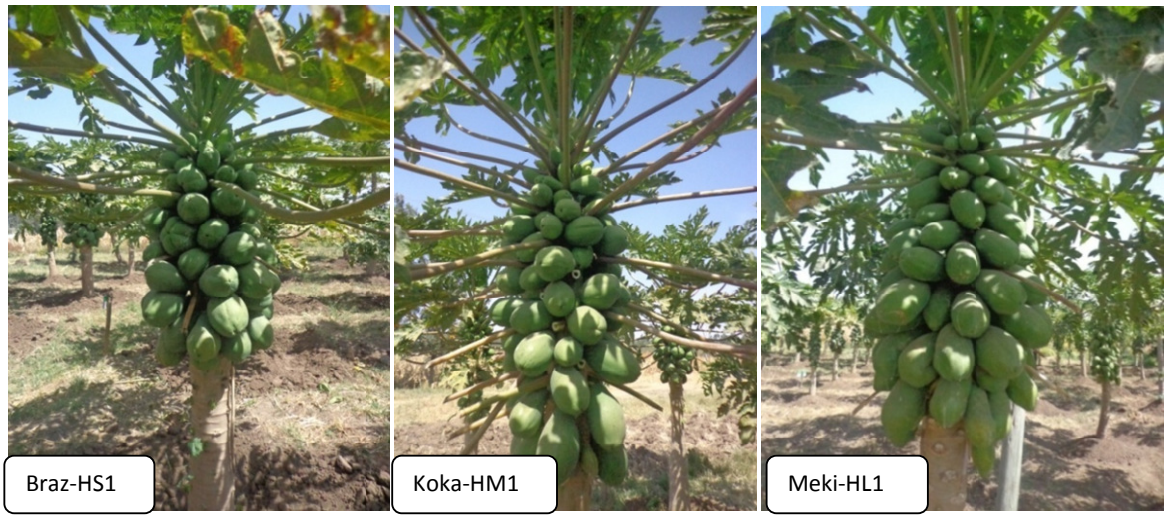


**Figure 2**. Field performance the three released papaya varieties Braz-HS1 (left), Koka-HM1 (middle) and Meki-HL1 (right)

**1.** ***Braz-HS1*** is a local designation (name) given for the released variety from small fruit set category. Its accession code was CMF078-L56. In this variety name; 'Braz' indicates the origin of the variety since it was introduced from Brazil. 'H' indicates that it is hermaphrodite type. 'S' indicates that the variety is in small fruit size category. Finally, '1' is to indicate it is the first variety to be released in this category.

**2.** ***Koka-HM1*** is a local designation (name) given for the released variety from medium fruit set category. Its accession code was KK103-L446. In this variety name; 'Koka' indicates the origin of the variety since it was locally collected from central rift valley area called Koka. 'H' indicates that it is hermaphrodite type. 'M' indicates that the variety is in medium fruit size category. Finally, '1' is to indicate it is the first variety to be released in this category.

**3.** ***Meki-HL1*** is a local designation (name) given for the released variety from large fruit set category. Its accession code was MK121-L516. In this variety name; 'Meki' indicates the origin of the variety since it was locally collected from central rift valley area called Meki. 'H' indicates that it is hermaphrodite type. 'L' indicates that the variety is in large fruit size category. Finally, '1' is to indicate it is the first variety to be released in this category.

**Characteristics of released varieties**

Detailed characteristics of the three released varieties; Braz-HS1, Koka-HM1 and Meki-HL1, are described in

**Table 6**. Description recently released hermaphrodite papaya varieties

| No | Variety | Morphology characteristics | | | | | | | | | Quality characteristics | | | | | | Productivity (t/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Height t to 1st flower | Fruit shape | Ridging of fruit surface | Shape of central cavity | Central cavity diam. (cm) | Fruit leng. (cm) | Fruit diam. (cm) | Fruit weight (g) | Fruit size category | Skin thickness | Flesh aroma | Fruit color | Flesh color | Fiber | Pulp TSS (°Brix) | |
| 1 | Braz-HS1 (CMF078-L56) | 50.0 | oval | Low | Zigzag | 3.8 | 13.5 | 8.8 | 432 | Small | Thick | Interm. | yellow | Reddish orange | Nil | 10.2 | 64.7 |
| 2 | Koka-HM1 (KK103-L446) | 89.0 | Pear | Interm | star shape | 3.9 | 14.1 | 9.1 | 559 | Medium | Thick | Interm. | Yellowish green | Reddish orange | Nil | 13 | 75.2 |
| 3 | Meki-HL1 (MK121-L516) | 97.7 | Pear | Low | Irregular | 3.9 | 18.2 | 10.4 | 923 | Large | Interm. | Mild | Yellowish | Bright yellow | Nil | 14.1 | 87.3 |

Table 6. The information is also fully described on Variety Registry Book of the year 2015 (MoA, 2015). Normally papaya plantations are harvested economic yield at least for the first three to four years after establishment (Samson, 1986). Total yields for three consecutive years were higher for the three released papaya varieties as compared to national average (Figure 1). Field performance of these varieties is presented in Figure 2.

Braz-HS1 was a small fruit sized hermaphrodite papaya variety with average fruit weight 472 grams. This variety is characterized as dwarf type since it started to flower in the shortest tree height. It fits for export market due to its small fruit size and good quality. The productivity of this variety was 64.7 t/ha. It has 176.9% yield advantage as compared to national average (23.37 t/ha) in the same year.

Koka-HM1 was a medium fruit sized hermaphrodite papaya variety with average fruit weight 559 grams. It was with high TSS (13.0) and medium fruit size that fits for local market. The productivity of this variety was 75.2 t/ha. It has 221.8% yield advantage as compared to national average in the same year.

Meki-HL1 was a large fruit sized and high yielder hermaphrodite papaya variety with average fruit weight 923 grams. It was with high TSS (14.1) and large fruit size that fits for processing and local market. The productivity of this variety was 87.3 t/ha. It has 273.6% yield advantage as compared to national average in the

same year.

## CONCLUSSIONS AND RECOMMENDATIONS

Pure papaya lines (varieties) have developed through continuous controlled pollination of the population maintained at Melkassa Agricultural Research Center. Selected lines were tested in multilocation and three outstanding hermaphrodite varieties such as Braz-HS1 (CMF078-L56), Koka-HM1 (CMF078-L56) and Meki-HL1 (MK121-L516) were released as first success in history of papaya research in Ethiopia. The three varieties have recommended to be produced in central rift valley and similar agro-ecologies of the country. The same research center is responsible to maintain the varieties and provide breeder and pre-basic seeds for research and multiplication purposes. Unlike many other fruit crops, means of propagation for papaya is just by seed. Any government and non-government development organizations as well as farmers could multiply next generation seeds for wide promotion of these varieties. Seed has to be produced through controlled pollination or using minimum isolation distance of 700m isolation to ensure genetic purity (ES, 2016). More research effort should continue to develop more varieties (pure line and/or hybrid) with high yielding, quality and disease resistant/tolerant.

## ACKNOWLEDGEMENT

The authors would like to acknowledge Ethiopian Institute of Agricultural Research (EIAR) and Melkassa Agricultural Research Center (MARC), for the financial allocation and all facilitations of this study. They would like to appreciate all collaborating centers and organizations such as Werer Agricultural Research Center (MARC), Ziway Prison Administration and Upper Awash Agro-Industry Enterprise and researchers, experts and support staffs who have contributed for the result.

## REFERENCES

Agrawal, R.L. (2002): Fundamentals of plant breeding and hybrid seed production. Oxford and IBH Publishing Co. Pvt. LTD, New Delhi.

CSA (2015): Agricultural sample survey: report on area and production for major crops, statistical bulletin 578: Central statistical authority, Addis Ababa, Ethiopia.

ES (2016): Quality Declared Papaya Seed Specifications: Ethiopian Standards, ES 03924-48:2016

FAOSTAT (2012): *Crops Production Data*: http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor

Josef, S.B. (2008): Production of papaya: A production manual, Provide in support of papaya extension program of the Ministry of Agriculture Land and Marine Resources, extension, training and information division, Trinidad and Tobago

MARC (2004): Progress Report of Melkassa Agricultural Research Center (*Unpublished*)

MoA (2015): Plant Variety Release, Protection and Seed Quality Control Directorate. Crop variety register: Ministry of Agriculture Issue No. 16

Nakasone, H. Y.; and Paull R. E. (1998): Tropical Fruits. Crop Production Science in Horticulture No. 7. CABI. University of Hawaii, Honolulu, USA.

Paull R. E. and Duarte O. (2011): Tropical Fruits, 2nd Edition, Volume 1. CABI International

Samson, J. A. (1986): Tropical fruits (2nd ed). Tropical Agriculture Series. Longman. Scientific and Tech

World map of top ten papaya producing countries [https://www.mapsofworld.com/world-top-ten/papaya-producing-countries.html]

## APPENDIXES

**Appendix Table 1**. Mean squares for papaya fruit yield computed for three years

| Source | TY1 | TY2 | TY3 | xTY |
|---|---|---|---|---|
| Rep | 4.09$^{ns}$ | 275.08$^{ns}$ | 182.43$^{ns}$ | 38.44$^{ns}$ |
| Var | 613.49$^{***}$ | 514.29$^{ns}$ | 281.28$^{ns}$ | 308.51$^{**}$ |
| Error | 41.99 | 268.11 | 163.08 | 72.02 |
| F value | 14.61 | 1.92 | 1.72 | 4.28 |
| Pr>F | <0.0001 | 0.1273 | 0.1681 | 0.0064 |
| CV | 20.2 | 17.5 | 14.3 | 12.8 |

**Appendix Table 2**. Mean squares for papaya fruit weight computed for three years

| Source | FW1 | FW2 | FW3 | xFW |
|---|---|---|---|---|
| Rep | 16263.3$^{ns}$ | 17911.5$^{ns}$ | 5359.7$^{ns}$ | 7140.4 |
| Var | 76169.2$^{***}$ | 148535.7$^{***}$ | 193829.1$^{***}$ | 118228.3$^{***}$ |
| Error | 9525.3 | 7447.9 | 7787.7 | 2868.4 |
| F | 8.00 | 19.94 | 24.89 | 41.2 |
| Pr>F | 0.0002 | <0.0001 | <0.0001 | <0.0001 |
| CV | 17.8 | 11.4 | 13.4 | 10.4 |