**ORIGINAL ARTICLE**

# Effect of intra-row spacing and variety on fruit yield and quality of fresh market tomato (*Lycopersicon esculentum* Mill.) under Jimma condition, Ethiopia

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## ABSTRACT

A field experiment was conducted at Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) research field during the 2009/2010 cropping season with the objective of investigating the performance of two determinate (Fetene and Bishola) and two indeterminate (Marglobe and local) tomato varieties each planted at intra-row spacings of 25, 30, 35 and 40 cm with 70 cm inter row spacing. The study was conducted by using 4x4 factorial design with three replications. Growth, yield and fruit quality parameters were recorded and analyzed using SAS version 9.2 computer packages. The results obtained showed that Fetane and Bishola planted at all tested spacings gave the highest branch number per plant and, reached 50% flowering within significantly ($P<0.001$) shorter period than the others. Moreover, Fetane was found to be superior to all the others ($P<0.001$) in early maturity, fruit length, fruit diameter, fruit weight, fruit pericarp and titratible acidity to all the others at all the intra-row spacings tested compared to all the others($P<0.001$) followed by Bishola variety. The determinate varieties (Fetene and Bishola) planted at intra-row spacing of 30-35 cm produced significantly ($P<0.001$) higher marketable fruit yield which in turn was found to be significantly and positively correlated with fruit diameter ($r=0.83^{***}$), fruit length($r=0.86^{***}$) and fruit weight ($r=0.82^{***}$). It can be concluded that tomato growers in the study area can use intra-row spacing of 30 cm for better fruit yield and quality of the determinate varieties, Fetane and Bishola, which performed far better than the Marglobe and local tomato varieties.

***Keywords***: Tomato Varieties, intra-row spacing, marketable fruit yield.

## INTRODUCTION

At present, tomato is grown worldwide with the exception of colder regions. It grows both on a small and commercial large scale as a cash crop by the vegetable growers (David, 2010). Tomato is among the most important vegetable crops and both fresh and processed tomato varieties are popular and economically important vegetable crops produced in Ethiopia.

According to Lemma et al. (2003) the total production of tomato in the Ethiopia has shown a marked increase recently, indicating that it became the most profitable crop providing a higher income to small scale farmers compared to other vegetable crops. However, the national average of tomato fruit yield under farmers' conditions in Ethiopia is very low and estimated at about 25 t/ha (Lemma 2002). A number of improved varieties and other agronomic packages have been recommended to the users to overcome the low productivity and quality of tomato in the country. And yet , the average national yield still remains very low and reported to be about 7 ton/ha (CSA, 2009), the value of which is less than 50% of the world average of 27 ton/ha (FAOSTAT, 2007). The production and productivity of the crop in Ethiopia is influenced by different factors among which improper plant spacing is the notable. According to Lemma *et al*. (2003) increasing production of the crop has a great role to strengthen the growing vegetable industries in the country. The authors further explained that plant spacing greatly influenced fruit yield in both fresh market and processing tomatoes. Mehla *et al*. (2000) also reported the importance of plant spacing on yield and quality parameters in tomato crop. Yield variation in tomato may occur due to disease infestation, lack of improved variety and variation in cultural practices like plant population per a given area. Tesfaye (2008), reported that plant spacing is the most important factor that affects yield and fruit quality of tomato. According to the author, in Ethiopia, plant spacing and fertilizer application rates were determined for tomatoes only at Melkassa research center and under vertisol and sandy loam soils of the Rift Valley regions of the country. These results and their respective recommendations cannot be applied for other tomato growing parts of the country that have completely different climate and soil condition. The Jimma zone of Oromia regional state is not exception to these conditions. The present work was therefore initiated with the following objectives: 1) To determine optimum plant population for better growth, fruit yield and quality of three released and one local tomato varieties, 2) To identify best performing variety under Jimma condition.

## MATERIALS AND METHODS

### Description of Study Area

This Experiment was conducted from December 2009 to October 2010 at Jimma University College of Agriculture and Veterinary Medicine (JUCAVM), located at 352 Km south west of Addis Ababa. Jimma(JUCAVM) is located at 7°42 N latitude and 36°50 E longitude and at altitude 1710 m a.s.l. The maximum and minimum temperature of the study area is 26.8 and 11.8°C, respectively, with relative humidity of 91% and mean rainfall of 1500 mm per annum.

### Experimental Materials and Design

The experimental materials consisted of 4 varieties, two determinate (Fetane and Bishola) and two indeterminate (Marglobe and Local) planted in 4 intra-rows spacing (25, 30, 35 and 40 cm) with 70 cm inter-rows for all spacings. Marglobe, Fetane and Bishola were collected from Melkassa Agricultural Research Center, while the local variety was collected from "Buture Gabisa" peasant association (Mana district) located at 15 km from the study site. The experiment was laid out in 4 x 4 factorial design with three replications. The size of each experimental plot was 7 $m^2$ (3.5 m wide and 2 m long). Treatments were randomly assigned to the experimental plots.

**Management of the Experiment**

Seeds of each tomato variety were sown in rows of 15 cm on well prepared seed bed of 1x10 m and covered with light soil and mulching grasses until emergence. The beds were watered with watering can followed by surface irrigation. The seedlings were thinned at 3 cm spacing within rows at first true leaf stage, followed by proper weeding and watering. Land preparation was done in advance to reduce diseases and insect pest incidence. Finally, hardened, healthy and uniform seedlings of pencil size were transplanted at an age of 30 days (MoARD, 2009).

The transplanted seedlings were watered and provided shade (for 10 days) and inorganic fertilizers of diammonium phosphate (DAP) and urea applied at the rate of 92 kg/ha P2O5 and 96 kg/ha N, respectively. All the phosphate fertilizer was applied at transplanting whereas nitrogen was given at two equal splits (at transplanting and 30 days after transplanting) as basal application (EARO, 2004). Plots were irrigated every other day at the beginning and at three days interval thereafter. Fungicides (Ridomil + MZ, 63%-3.5 kg per ha) were sprayed on 7th -10th days after transplanting until 20 days before first harvest as recommended by Lemma (2003). Weeding, cultivation, watering, staking, chemical spray etc. were done as required.

**Statistical analysis**

Data were subjected to analysis of variance using SAS version 9.2. Single and interaction effect of factors were determined using the GLM procedure of SAS. Least Significant Difference (LCD) was used to compare treatment means when there was statistically significant difference ($P<0.05$).

## RESULTS AND DISCUSSION

**Number of primary branches per plant**

The results of mean branch number, plant height and days to first harvest of the four tomato varieties planted at four different intra-row spacings are shown in Table 1. The two determinate varieties (Fetane and Bishola) planted at all tested spacings (25, 30, 35 and 40 cm) gave significantly higher ($P<0.001$) number of branches per plant (7.06 -7.73) than all the others, with out showing significant difference between each other, followed by Marglobe variety (V1). The results of this study showed that the determinate tomato varieties (V2 and V3) planted at different intra-row spacing were superior to indeterminate varieties (V1 and V4) planted at the same intra-row spacing in number of branches/plant. As shown in Table 1, Marglobe variety planted at 40 cm spacing resulted in significantly higher ($P<0.001$) number of branches/plant than Marglobe variety planted at 25 and 30 cm intra-row spacings. On the other side, least number of branches/plant (5.78 and 5.80) was obtained from local variety planted at intra-row spacing of 25 and 30 cm, respectively. The better performance of the determinate type varieties in terms of number of branches/plant could be attributed to variation in genetic behavior. The results of this study tends to recommend intra-row spacing of 30 cm and 40 cm for short set type Fetane and Bishola (V2 and V3) and for tall set Marglobe (V1) and local varieties, respectively for better branch number per plant.

The result of this study is in agreement with that of Muhammad and Muhammad (2002) who reported increased number of branches per plant in determinate type tomato plants than indeterminate type.

**Plant height**

The results of mean plant height of the four tomato varieties planted at four different intra-row spacings are also shown in Table 1. The maximum plant height was recorded from Marglobe tomato variety (V1) planted at intra-row spacing of 35 and 40 cm and from local variety (V4) planted at intra-row spacing of 40 cm. The results of this experiment indicated that both indeterminate type varieties (V2 and V3) performed similarly under all the intra-row spacing, while the indeterminate type tomatoes varieties (V1 and V4) required wider (35 and 40 cm) intra-row spacing for better performance in terms of plant height (Table 1). Thus the results of this experiment indicated that the combination of varieties

and wider intra-row spacing resulted in maximum plant height for both indeterminate type varieties, while the short set varieties Fetane and Bishola gave the highest plant height under all spacings. It could be suggested that for those indeterminate type tomatoes, Marglobe and Local varieties, wider plant spacing 35 and 40 cm intra-row spacing, and for determinate type Fetane and Bishola, closer spacing of 30 cm resulted in better plant height. This could be attributed to the maximum competition of plants for nutrient; light and air for those tall set varieties and variation in genetic make up for all varieties. Various studies (Abdalla, 2003; El Naim, 2003; Nile, 2003) revealed differences between cultivars in plant height under different levels of plant spacing.

**Days to 50% flowering**

The mean days to 50% flowering of the different tomato varieties planted at different intra-row spacings are shown in Figure 1.

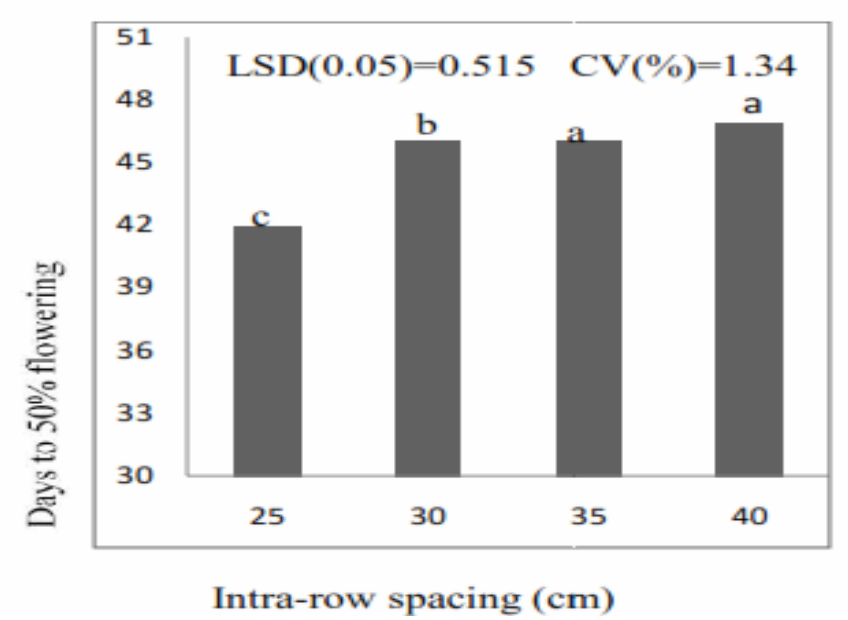


Figure 1. Main effect of intra-row spacing on days to 50% flowering

The results obtained showed that there was statistically significant (P< 0.001) difference between the varieties planted at different intra-row spacing in days to 50% flowering. As shown in Figure 1, varieties planted at 25 cm intra-row spacing attained 50% flowering within a short period of time (45 days) indicating that densely populated plants attained 50% flowering two days earlier than sparsely populated plants. In line with these results, El-Naim (2003) confirmed that closer spacing could reduce vegetative growth and enhance flower formation. The result obtained also showed that there was significant difference between varieties (P<0.001) in days to 50% flowering (Figure 2). Fifty percent flowering was achieved by Fetane cultivar, within 42 days, followed by Bishola cultivar that achieved 50% flowering within 44 days. Local variety achieved 50% flowering 10 and 8 days latter than Fetene and Bishola varieties, respectively. The superiority in maturity of the two determinate cultivars (Fetane and Bishola) could be due to the genetic variation in maturation period of the varieties. Therefore, the result of this study tends to indicate that determinate type tomato varieties (V2 and V3) could be produced at relatively low cost due to short period of harvesting time. Nile (2002) observed differences among cultivars with regard to time to 50% flowering and maturity.

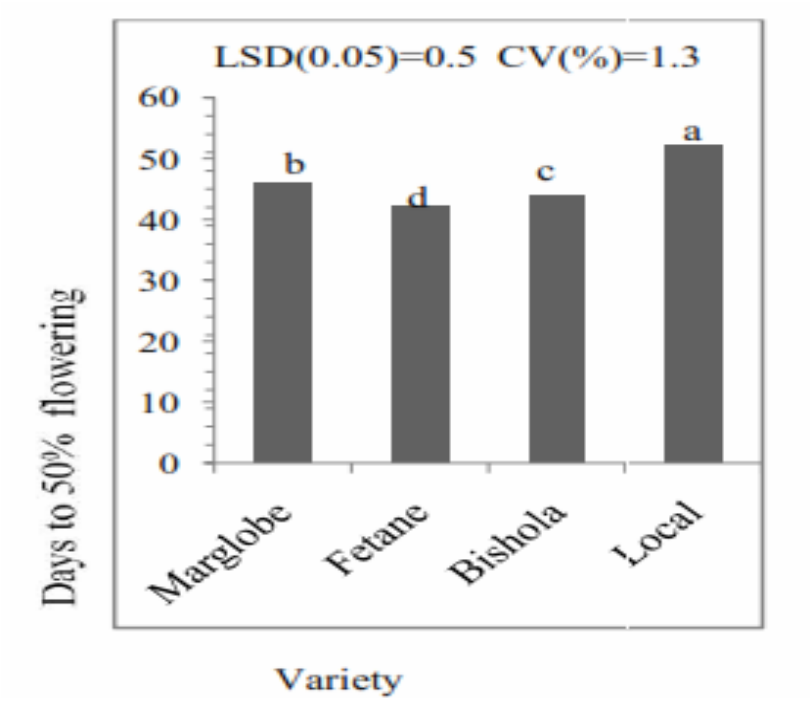


Figure 2. Main effect of varieties on days to 50% flowering

**Days to first harvest**

The mean days to harvest of the different tomato varieties planted at different intra-row spacings are shown in Table 1. Fetane variety planted at all the intra-row spacing (25, 30, 35 and 40 cm) was found to be significantly early ($P<0.001$) in maturity than the others as measured by mean number of days at the first harvest. With Fetane variety, maturity days (days to the first harvest) significantly increased ($P<0.001$) with increase in intra-row spacings, indicating that Fetane planted at closer intra-row spacing, reached maturity earlier (76.33 days) than the others. Indeterminate type local variety, planted at wider intra-row spacing of 35 and 40 cm, reached maturity on the 96 and 97 days respectively, showing that the local variety (V4) planted at 35 and 40 cm intra-row spacings required about 3-weeks(21 days) of additional time to attain maturity as compared to Fetane variety. The early maturity of Fetane at closer intra-row spacing could be due to maximum plant competition to nutrition, air and other growth factors, there by reduced vegetative growth of plants which in turn enhanced flower formation early. The late maturity of lower plant population could be due to genetic variation of tall type tomato crop. These results were in line with the findings of (Tesfu and Charles, 2010) who revealed that increasing planting density appeared to shorten days to maturity.

Table 1. Mean branch number, plant height and days to first harvest as affected by the interaction effect of variety and intra-row spacing

| Varieties x Intra-row spacing (cm) | Branch number /plant | Plant height (m ) | Days to first harvest |
|---|---|---|---|
| V1 x S1 | 6.10 fg | 1.52cd | 91.00 g |
| V1 x S2 | 6.23 f | 1.54 bc | 92.66 f |
| V1 x S3 | 6.40 ef | 1.58ab | 95.00 c |
| V1 x S4 | 6.66 e | 1.58ab | 96.33 b |
| V2 x S1 | 7.06ab | 0.91 h | 76.33 m |
| V2 x S2 | 7.50a | 0.92 h | 77.66 l |
| V2 x S3 | 7.50a | 0.90 h | 79.00 k |
| V2 x S4 | 7.73a | 0.94 gh | 80.33 j |
| V3 x S1 | 7.06 ab | 0.98 g | 85.66 i |
| V3 x S2 | 7.40ab | 0.97 g | 86.00 i |
| V3 x S3 | 7.46a | 0.98 g | 85.66 i |
| V3 x S4 | 7.60a | 1.03 fg | 88.00 h |
| V4 x S1 | 5.76 g | 1.45 e | 93.33 e |
| V4 x S2 | 5.80 g | 1.48 de | 94.33 d |
| V4 x S3 | 6.73 de | 1.57 b | 96.00 b |
| V4 x S4 | 7.03 cd | 1.62a | 97.66a |
| LSD (0.05) | 0.33 | 0.043 | 0.65 |
| CV (%) | 2.16 | 2.10 | 0.77 |

Mean within the same column with common superscript letter are not significantly different (P<0.001)
V1=Marglobe variety, V2=Fetane, V3= Bishola, V4= Local, S1=Spacing 25 cm, S2=30 cm, S3= 35 cm, S4= 40 cm

## Yield Parameters

### Fruit length and diameter

The yield parameters of the the tomato varieties planted at different intra-row spacings are shown in Table 2. The results obtained showed that all the four varieties tested tended to increase in fruit length with increase in intra-row spacings. The longest fruit length of 6.20 cm, the value of which is significantly higher (P<0.001) than the others. There was no significant difference between the Fetane variety planted at 30, 35 and 40 cm intra-row spacings in fruit length (P<0.001). Fruit length ranging between 5.97 and 6.17 cm were recorded from Bishola variety planted at all the four intra-row spacings. In which the Bishola variety planted at 30 and 40 cm intra- row spacings are significantly higher(P<0.001) than the Bishola variety planted at 25 and 30 cm intra-row spacings in fruit length. In the contrary significantly shorter fruit lengths were recorded from local variety planted at all the four intra-row spacings as compared to all the other varieties(P<0.001). Similarly significantly longer (P<0.001) fruit diameter (7.28-7.42 cm) was recorded from Fetane planted at intra-row spacing of 35 - 40 cm intra-row spacing. Marglobe and Bishola planted at intra-row spacing of 40 cm were comparable in fruit diameter (6.32-6.42 cm). The smallest fruit length and diameter were obtained from local landrace planted at intra-row spacings of 25 and 35 cm. The

results of this study indicated that in the case of indeterminate type tomato reduction in plant population per unit area resulted in increased fruit length and diameter both of which are attributed to genetic make-up and plant population. The result of this study is in conformity with Ahmad and Singh (2005) who reported that wider spacing minimizes competition for nutrients, water and radiation which in turn favored fruit size. Ojo *et al*. (2013) also reported the lowest fruit diameter, weight of fruits/plant and fruit yield recorded in local tomato variety compared to the improved varieties. Wahundeniya *et al.* (2005) also described that fruit size is very important parameter for fresh market tomato end users, but less important for processing purpose. According to Resh (2003) fruit size determines the consumer preference in tomato crop.

**Average fruit weight (g)**

As shown in Table 2, Significantly higher ($P<0.001$) mean fruit weight(120 – 121.66 g) was obtained from Fetane planted at intra-raw spacing of 35- 40 cm($P<0.001$), whereas, significantly smaller fruit weight (50.73g) was obtained from local variety planted at intra-row spacing of 25 cm ($P<0.001$) The results of this study clearly showed that the determinate fresh market tomato variety (Fetane) planted at intra-row spacing of 35-40 cm had more than two fold average fruit weight than that of indeterminate type (Marglobe and local). The results of this study are in agreement with that of Muhammad and Singh (2007) who reported higher tomato fruit weight was obtained from wider intra-row spacing.

**Marketable yield per hectare**

As shown in Table 2, both Fetane and Bishola planted at intra-row spacing of 30 and 35 cm produced significantly higher ($P<0.001$) marketable fruit yield than the indeterminate type varieties planted at similar intra-row spacings. Within the indeterminate both Marglobe and local varieties performed better at intra-row spacings of 35-40 cm than that of 25-30 cm intra-row spacings. According to the result of this study for short set type varieties of Fetane and Bishola are found to be the best producer of marketable yield at 30-35 cm intra-row spacings whereas, both Marglobe and local type were found to be better in the production of marketable yield at intra-row spacings of 35-40 cm. The better performance of determinate varieties at 30-35 cm intra-row spacings could be due to greater canopy and growth habit of determinate type varieties (Fetane and Bishola) which could be protected the fruits from sun scalding, thereby contributed to production of marketable damage free fruit. The results of this study showed that, marketable yield could be increased up to 16.3t/ha with the use of both relatively early-maturing (determinate) and late maturing (indeterminate) fresh market tomato varieties in combination with optimum intra-row spacings. Uddin *et al.* (1997) revealed that wider spacing with variety interaction gave the higher marketable tomato fruit yield.

Table 2. Mean values of fruit length, fruit diameter, average fruit weight and marketable yield

| Varieties x Intra-row spacing (cm) | Fruit length (cm) | Fruit diameter (cm) | Av. fruit weight (g) | Marketable yield (t/ha) |
|---|---|---|---|---|
| V1 x S1 | 4.28$^{dee}$ | 6.09$^{d}$ | 63.66$^{g}$ | 26.23$^{f}$ |
| V1 x S2 | 4.24$^{e}$ | 6.16$^{cd}$ | 87.33$^{bef}$ | 37.90$^{de}$ |
| V1 x S3 | 4.62$^{cde}$ | 6.33$^{bcd}$ | 98.50$^{cd}$ | 42.20$^{cd}$ |
| V1 x S4 | 5.24$^{abcd}$ | 6.46$^{bc}$ | 111.66$^{ab}$ | 40.66$^{cd}$ |
| V2 x S1 | 5.17$^{bcd}$ | 6.26$^{bcd}$ | 76.66$^{f}$ | 34.30$^{e}$ |
| V2 x S2 | 5.43$^{abc}$ | 6.59$^{b}$ | 86.00$^{def}$ | 50.60$^{ab}$ |
| V2 x S3 | 5.36$^{abc}$ | 7.28$^{a}$ | 121.66$^{a}$ | 54.26$^{a}$ |
| V2 x S4 | 6.20$^{a}$ | 7.42$^{a}$ | 120.00$^{a}$ | 44.76$^{c}$ |
| V3 x S1 | 5.97$^{ab}$ | 6.19$^{cd}$ | 86.66$^{def}$ | 34.76$^{e}$ |
| V3 x S2 | 5.99$^{ab}$ | 6.11$^{cd}$ | 87.33$^{def}$ | 51.50$^{a}$ |
| V3 x S3 | 6.17$^{a}$ | 6.16$^{cd}$ | 98.00$^{cde}$ | 51.93$^{a}$ |
| V3 x S4 | 6.16$^{a}$ | 6.32$^{bcd}$ | 103.33$^{bc}$ | 45.06$^{bc}$ |
| V4 x S1 | 2.69$^{fg}$ | 4.24$^{e}$ | 50.73$^{h}$ | 10.13$^{g}$ |
| V4 x S2 | 2.92$^{fg}$ | 4.20$^{e}$ | 51.50$^{gh}$ | 12.30$^{g}$ |
| V4 x S3 | 3.16g | 4.24$^{e}$ | 55.33$^{gh}$ | 14.30$^{g}$ |
| V4 x S4 | 3.18$^{f}$ | 4.26e | 85.33$^{ef}$ | 27.36$^{f}$ |
| LSD (0.05) | 0.96 | 0.94 | 12.73 | 5.65 |
| CV (%) | 2.82 | 2.76 | 6.56 | 6.97 |

Mean within the same column with common superscript letter are not significantly different (P<0.001)
V1=Marglobe variety, V2=Fetane, V3= Bishola, V4= Local, S1=Spacing 25 cm, S2=30 cm, S3= 35 cm, S4= 40 cm

## Quality parameters

### Fruit pericarp thickness

The highest fruit thickness was obtained at wider intra-raw spacing (35 and 40 cm), while at closer spacing (25 and 30 cm) similar value was obtained, which was less than that of plants planted at wider spacing. This clearly indicated that decreasing plant density is valuable to achieve better fruit quality due to minimum plant competition for growth factors like light and essential nutrient.

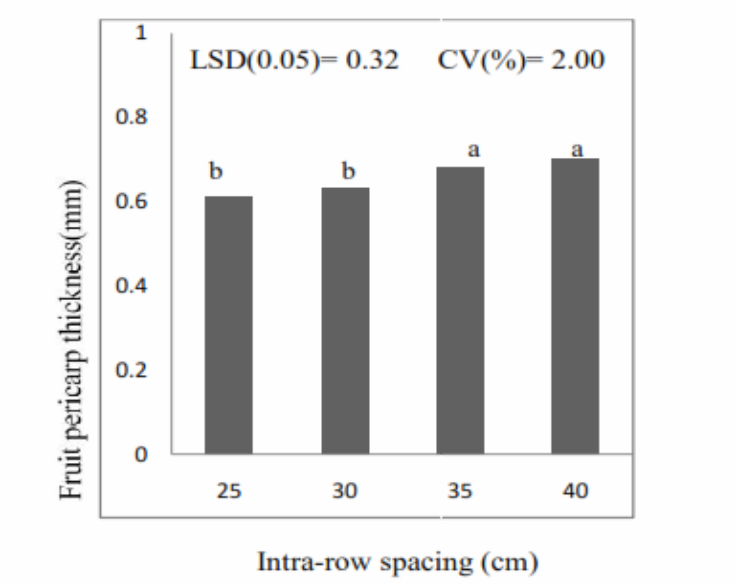


Figure 3. Effect of intra-row spacing on fruit pericarp thickness

The highest value of pericarp thickness was recorded for Bishola (0.71 mm) and Fetane (0.70 mm), followed by Local. The lowest fruit pericarp thickness (0.59 mm) was obtained from Marglobe variety at intra-row spacing of 25 cm. The softness of fruit pericarp could increase the susceptibility of the fruit to disease.

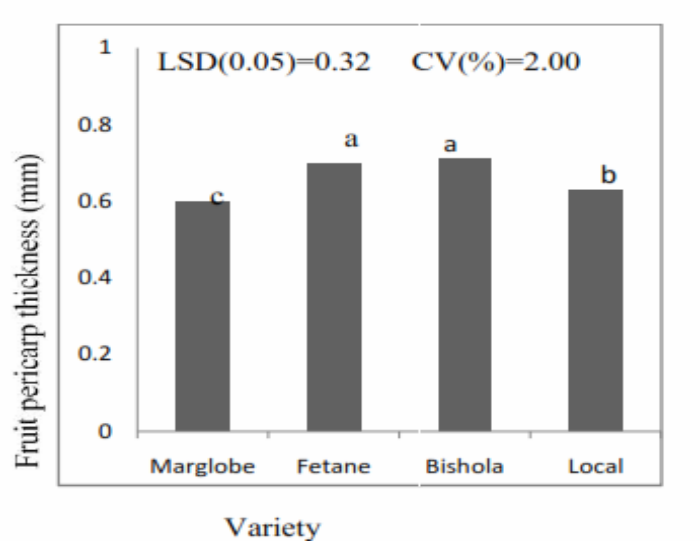


Figure 4. Effect of variety on fruit pericarp thickness

Thick pericarp is a useful character as far as post harvest handling is concerned in transportation. So it could be an added advantage to have a thicker pericarp when selecting tomato varieties. Firmness of pericarp tissue is a key for long storability. Round and thin-skinned cultivars such as Marglobe, Heinz 1350 and Moneymaker are highly perishable as compared to pear or cylindrical and thick skinned ones, such as Roma VF (Lemma, 2002). Lee and Kader, 2000), indicated that selection of the genotype with the highest quality, shelf life and yield for a given commodity is a much more

important factor than climatic conditions and cultural practices.

**Titratable acidity**

The results of titratable acidity values of the four tomato varieties planted at different intra-row spacings are shown in Figure 5. The titratable acid recorded was significantly higher (P<0.001) for Fetane cultivar (40%) followed by that of Bishola and Marglobe (0.39%), whereas the local variety had titrabtable acidity of 0.33%. This result is in agreement with that of George *et al.* (2004) who revaluated that titratable acidity in fruit of twelve tomato genotypes ranging between 0.256 and 0.704 g per 100 $g^{-1}$. Larger fruits had better titratable acidity due to variability in fruit weight. This is in agreement with Tittonell *et al.* (2001) who reported that large sized tomato fruit had higher acidity, which supports the present finding.

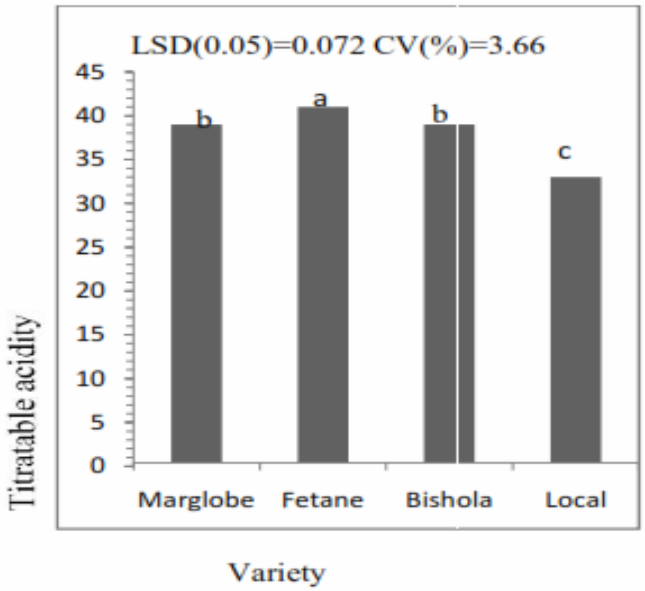


Figure 5. Effect of variety on titratble acidity

Saliba-Colombani *et al.* (2001) also illustrated that total sugars (primarily reducing sugars) content of tomato are positively correlated with pH and titratable acidity. Nonvolatile compounds such as sugar, titratable acidity and soluble solids play a great role in determining flavor of the fruit. Georgelis (2002) reported a positive correlation between sugar and pH as well as sugar and titiratable acidity, indicating that plants with high sugar contents have more free organic acids and less hydrogen ion concentration than plants with low sugars.

## CONCLUSION

In the study area, farmers get lower yield mainly due to inappropriate agronomic practices, plant spacing is one of the most among the notable reasons of low productivity of tomato, though the present study was conducted to investigate the effect of different intra-row spacing levels on yield and yield quality of four fresh market tomato varieties. The finding showed significant differences among plant spacing and varieties for most quality and yield characters. From the finding of this study it could be concluded that appropriate plant spacing with variety selection could be practiced to increase the yield and quality of fresh market tomato production. Tomato growers in the study area should be encouraged to use intra-row spacing 30 cm x 70 cm with the determinate type of Fetane and Bishola varieties to produce better fruit yield and quality, since these perform far better than the Marglobe and unimproved local tomato varieties. Thus, growing of

determinate type tomato for fresh market can reduces cost of production which could be minimized due to short period of harvesting time. However, it is necessary to undertake further researches including optimization of fertilizer and water requirement for the different varieties under different intra- and inter row plant spacing in different growing conditions and type of production to understand their yield performance.

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