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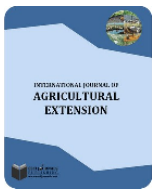

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EFFECT OF INTRA-ROW SPACING ON PLANT GROWTH, YIELD AND QUALITY OF TOMATO (*Lycopersicon esculentum* Mill) VARIETIES AT MIZAN-AMAN, SOUTHWESTERN ETHIOPIA

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ABSTRACT

The productivity of tomato is influenced mainly by environmental factors, agronomic practices and cultivar potential. Accordingly, a field experiment was conducted at Mizan-Aman, southern Ethiopia in 2016/ 2017 to evaluate the effect of intra-row spacing (20, 30, 40 and 50 cm) on the performance of three tomato varieties(Fetan, Bishola and Roma VF) with the constant inter-row spacing of 70 cm in completely randomized block design with three replications. Data on crop phenology, growth performance, yield and quality parameters were recorded and subjected to analysis of variance using SAS version-9 software. Results of the study indicated that both intra-row spacing and variety had a significant effect on phenology as well as parameters including; the number of branches, the number of fruit cluster and fruit per plant, fruit weight, total fruit yield, marketable and unmarketable yield and total soluble solids (TSS). However, the number of fruits per cluster, fruit shape index, titratable acidity (TA) and pH were significantly different only among varieties, while plant height was significantly affected by intra-row spacing. Closer spacing enhanced early maturity, while wider intra-row (50 cm) produced a maximum number of branches, cluster and fruits per plant, fruit weight, unmarketable yield and TSS. Generally, 20 and 30 cm intra-row spacing was found to be suitable for the production of maximum total and marketable yield. From the three tomato varieties, Fetan was early maturing with the highest total and marketable yield. The varieties were also significantly different in fruit weight, with the highest value obtained from Bishola followed by Fetan. The outcome of this study revealed that, the intra-row spacing of.30 cm and variety Fetan could be promoted for production in Mizan-Aman and similar agro-ecologies.

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INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) belongs to the Solanaceae family and self- pollinating the annual crop. Tomato requires warm, clear, dry conditions, and altitudes ranging between 700 and 2000 meters above sea level. The total production of tomato in Ethiopia has shown an increase in the market and became the most profitable crop providing a higher income to small scale farmers compared to other vegetable crops (Lemma and Yayeh, 2003). However, the average yield of tomato in Ethiopia is lower, ranging from 6.5-24 metric tons/ha, which is very lower even by the African standard Gemechis *et al.* (2012). The productivity of tomato is influenced by different factors among which

environmental conditions, agronomic practices and varietal potential, however blanket recommendations of agronomic packages for all tomato producing areas could contribute to the yield reduction since the agro-ecology of production may be quite different from areas where the recommendation was made.

Consequently, the productivity of tomato in Mizan-Aman is very low since the farmers often use any available tomato variety with undefined spacing. Considering the importance of tomato for domestic consumption and export it is very crucial to increase its productivity and quality. Especially availability of agro-specific variety with optimum agronomic practices including plant spacing would be vital to enhance tomato production and increase the livelihood of the community in the study area. This study aimed to evaluate the response of tomato varieties in different intra-row spacing, to determine optimum intra-row spacing and identify best performing variety with optimum intra-row spacing.

MATERIALS AND METHODS

The study was carried out at Mizan-Aman which is located in Southwestern Ethiopia, 561 km Southwest of Addis Ababa with the geographical coordinate of 6059' N and 35035' E having an altitude of 1350 m above sea level. The area receives an average annual rainfall of 1546 mm and long-term average maximum and minimum temperatures are 40°C and 20°C, respectively. The soil is characterized as clay-loam with 5.7 pH value. The experiment was factorial in RCBD arrangement with three tomato varieties (Fetan, Bishola and Roma VF) described in Table 1 tasted in four Intra row spacing (20, 30, 40 and 50 cm) while having constant 70 cm inter-row spacing. Plant population per plot differed along with the varied intra-row spacing within constant four rows (Table 2). The spacing between adjacent plots within a block and replications were 1m and 1.5 m, respectively.

Table 1. Description of tomato varieties used in the study conducted in 2016/17 at Mizan-Aman.

Description	Fetan	Bishola	Roma VF
Year of release	2005	2005	
Released by	Melkassa agricultural research centre	Melkassa agricultural research center	
Altitude (masl)	700-2000	700-2000	700-2000
Growth habit	Determinate	Determinate	Determinate
Unique character	Early maturing and Concentrated fruit yield	Large fruit size, green shoulder fruit colour before mature	Globular fruit shape
Utilization	Fresh	Fresh	Fresh
Maturity days	78-80	85-90	95-100
Research yield (qt/ha)	454	340	400

Source: - Ministry of agriculture and rural development, 2009 and Nego *et al.* (2015).

Table 2. Treatment combinations of the study conducted in 2016/17 at Mizan–Aman.

Variety	Intra-row spacing	Plant population per hectare
Roma VF (control)	20	68,571
	30	45,714
	40	34,286
	50	25,714
Bishola	20	68,571
	30	45,714
	40	34,286
	50	25,714
Fetan	20	68,571
	30	45,714
	40	34,286
	50	25,714

The study was conducted from November 19, 2016, to April 13, 2017. Seedlings were raised in nursery beds after being sown in rows spaced 15cm apart and covered lightly with fine soil. The seedlings were then thinned until an intra-row spacing of 3 cm was achieved. The recommended 75kg/ha Phosphorus and 50 kg/ha Nitrogen fertilizer were applied (unpublished). Proper Management practices (watering, weeding, mulching shading) were followed to produce healthy seedlings. The recommended phosphorus fertilizer with a rate of 92 kg P_2O_5/ha was applied just before transplanting in the form of DAP. Nitrogen was applied in the split application in the form of urea with the rate of 46 kg N/ ha 23kg at transplanting and the rest 23kg, six weeks after transplanting. The seedlings were then carefully transplanted to the experimental plots 6 weeks after emergence. Recommended agronomic practices such as weeding, cultivation, irrigation, fertilizer application, staking and disease management were carried out uniformly during the growing season for all plots.

Data Collection and Analysis

Data were collected and analyzed on phenology, growth, and yield and fruit quality of the three tomato varieties.

Crop Phenology and Growth

Days to flower initiation estimated as several days from transplanting to the first flowering in each plot, days to flowering as number days of from transplanting to 50% flowering, days to fruiting from the date of transplanting to 50% of plants bear fruits and days to maturity as several days from transplanting to the day when 50% of the plants reached for first picking.

Growth parameters like plant height at flowering were measured from the ground level to the main apex, the number of branches per plant was counted at the beginning of fruit maturity while the number of leaves per plant was recorded from five randomly selected plants per plot. at two weeks interval starting from crop emergence till 50% of plants got bloomed

Yield Parameters

Tomato fruits were handpicked at a full-ripe stage of fruit clusters per plant, number of fruit per cluster and mean number of fruit per plant were counted from five randomly selected plants in each plot, whereas average fruit weight was calculated from randomly selected 10 marketable fruits from the successive (1st, 2nd and 3rd) harvests as:

$$\text{Average fruit weight} = \frac{\text{Total fruit weight}}{\text{Number of fruits}}$$

The total fruit yield (t/ ha) was also calculated from the central two rows as the total weight of fruits of the successive harvests and converted into hectare bases.

Quality Parameter

The marketable fruits selected as defect-free such as free of damage by insects, birds, diseases and sunburn for quality analysis. Accordingly, pericarp thickness (cm) was recorded by selecting ten fruits of different size and cut into two halves through the equator and the thickness of the pericarp measured by a calliper. Similarly, fruit shape index was calculated by the ratio of fruit length to width from ten selected fruits. Total soluble solid was also determined by placing a drop of juice sample in a refractometer (CE S. NO. AO 2371), while total soluble solids and fruit pH were determined by selecting three ripened sample fruits from each plot after which 25 ml of juice was extracted from each and poured into a beaker and the juice was stirred by a stirring bar and electrodes were then inserted into the beaker and finally the pH of each fruit was recorded. Titratable acidity (TA) was obtained by titrating 10 ml of tomato juice with 0.1 N NaOH. The result was expressed as grams of citric acid per 100 g of fresh tomato weight.

Data Analysis

The data were subjected to Analysis of variance (ANOVA) using statistical analysis software (SAS version 9.0) with the general linear model procedure. Mean separation was done using Fisher's Least Significant Difference (LSD) test at 5% probability level.

RESULTS AND DISCUSSION

Phenological Parameters

The main factors, variety and intra-row spacing significantly influenced days to flower initiation. Flower initiation in Fetan was significantly earlier than the other two varieties, which were statistically similar in performance (Table 3). The variation in days to flower initiation among the tomato varieties is likely to be related with differences in their inherent genotypic variation, as supported by the earlier findings of Nego *et al.* (2015) who reported that there was significant variation among tomato variety in days to flower initiation.

In the current study, days to flower initiation also increased with increasing intra-row spacing in which plants grown at wider spacing (40 and 50cm) took longer time to initiate flower than closer (20 and 30cm) intra-row spacing (Table 3). The observed time differences might be due to less competition among plants for growth resources at a wider intra-row spacing that increased the period of vegetative growth.

The main effects of intra-row spacing and variety on days to flowering were significant. Days to the flowering of variety Fetan was significantly earlier than both Bishola and Roma VF (Table 3). The observed differences among varieties in days to flowering were in line with the research findings of authors Dessie and Jobre (2004); Nego *et al.* (2015) and Meseret *et al.* (2012). On the other hand, increasing intra-row spacing from 20 cm to 50 cm resulted in delaying the time to flowering from 44.9 to 48.1 days (Table 3). This is mainly due to competition for light and nutrient is likely to be relatively low in plants with a wide intra-row spacing which eventually caused a delay in flowering Getahun and Bikis (2015). The analysis of variance of the current study for the main effect of variety and intra-row spacing on days to fruiting also revealed a very highly significant difference. Similar to days to flower initiation and flowering, days to fruiting of variety Fetan was significantly shorter than both Roma VF and Bishola varieties (Table 3). The variation in days to fruiting among the tomato varieties has shown an association with differences in flowering and fruiting characters of the three tomato varieties, which is in agreement with the findings of Nego *et al.* (2015) and Meseret *et al.* (2012), who reported that there was significant variation among tomato varieties in days to fruiting. In the current study, the time to fruiting also increased with increasing intra-row spacing from 20 cm to 50 cm (Table 3). This could also be due to higher competition of plants for growth resources in the closer intra-row spacing that may have led to stress and ultimately set fruit early instead of continuous vegetative and prolonged growth. The results of this experiment are in line with the finding of Getahun and Bikis (2015), which states that tomato plants with narrow intra-row spacing produced fruits earlier than plants with wide spacing. Varietal differences and intra-row spacing significantly influenced days to maturity. Variety Fetan matured significantly earlier followed by Bishola which also had significant difference with Roma VF variety. The variation in days to maturity among the tomato varieties is associated with differences in days to flowering and fruiting among varieties. The finding of this research was also in line with Meseret *et al.* (2012) who reported that there is significant variation among tomato varieties in days to maturity. In the current study, time to maturity increased with increasing intra-row spacing, in which the plants grown in wider spacing (50 cm) took more days to mature than closer Intra- row spacing (20 cm) (Table 3). This is because growing resource demand is usually higher in densely populated plants because of high competition for nutrient, light and water resulting in faster growth.

Table 1. The effect of intra-row spacing on the phenology of tomato varieties in the study conducted at Mizan-Aman during 2016/17 cropping season.

Treatment	Days to flower initiation	Days to flowering	Days to Fruiting	Days to maturity
		Variety		
Roma VF	43.5a	53.3a	73.3a	96.3a
Bishola	42.5a	51.2b	71.3b	83.3b
Fetan	31.2b	35.3c	53.3c	78.4c
LSD (0.05)	1.08	1.39	1.69	2.31
		Intra-Row spacing(cm)		
20	38.3b	44.9c	64c	84.0b
30	38.4b	46.3bc	65.7bc	85.4ab
40	39.8a	47.3b	66.7b	86.7a
50	39.7a	48.1a	67.67a	87.9a
LSD (0.05)	1.25	1.61	1.95	2.66
CV (%)	3.28	3.53	3.03	3.16

LSD(5%)= Least significant difference at P= 0.05, CV(%)= coefficient of variation in percent

Means with the same letter(s) within a column are not significantly different at 5% level of significance.

Growth Parameters

Intra-row spacing showed a significant difference in plant height, despite the main effect of variety and the interactions of the two factors were not significant. The maximum plant height was recorded from 20 and 30 cm intra-raw spaced plants (Table 4). Generally, the increase of Intra- row spacing from 20 cm to 50 cm decreased the mean plant height from 50.91 to 40.16 cm. Increases in plant height at closer intra-raw spacing are likely to be associated with more competition among plants for solar radiation, which is in agreement with the finding of Seid *et al.* (2013), The analysis of variance revealed a significant branch number difference among tomato varieties and intra-row spacing, although variety and intra-row spacing did not significantly interact to influence branch number. The maximum number of branches was counted from variety Fetan followed by Roma VF as indicated in Table 4. The difference obtained could be due to genetic makeup of the varieties kept under investigations. Current findings are similar to those of Regassa *et al.* (2016) and Meseret *et al.* (2012).

Yield Parameters

The maximum number of fruit cluster per plant was obtained from variety Fetan which was statistically similar to the number of clusters obtained from Roma VF (Table 5). A number of fruits clusters per plant also increased with increasing intra-row spacing. The maximum number of clusters per plant was recorded from 50cm intra-row spaced plant followed by 40cm (Table 5).

The number of clusters per plant at wider intra-row spacing could be related to a greater number of branches as compared to narrow intra-row spaced plants. This result was similar to the finding of Ara *et al.* (2007).

Table 2. The effect of intra-raw spacing and tomato varieties on growth parameters of tomato in the study conducted in Mizan-Aman during 2016/17 cropping season.

Treatment	Plant height(cm)	Leaf Number	Branch Number
Variety			
Roma VF	42.85	35.18	4.75b
Bishola	42.47	31.82	3.83c
Fetan	48.25	38.75	5.56a
LSD(0.05)	NS	NS	0.65
Intra-Row spacing(cm)			
0	50.91a	31.5	3.87b
30	47.11a	40.78	4.18b
40	39.911b	33.22	5.08a
50	40.16b	35.47	5.73a
LSD (0.05)	6.37	NS	0.75
CV (%)	18.87	19.82	16.35

LSD (5%)= Least significant difference at P= 0.05, CV(%)= coefficient of variation in percent

Means with the same letter(s) within a column are not significantly different at 5% level of significance.

The Number of Fruits per Cluster and Per Plant

The analysis of variance of this study showed significant differences in the number of fruits per cluster and per plant among tomato varieties. However, the interaction between the two factors did not significantly influence the number of fruits per cluster. The maximum numbers of fruit per cluster and per plant were recorded from Roma VF which were statistically similar with variety Fetan (Table 5).

The significant differences observed in fruit number per cluster and per plant among the tomato varieties are likely to be related to genetic differences. This result was in line with the finding of Meseret *et al.* (2012); Tigist (2008) and Dessie and Jobre (2004) who confirmed the existence of significant variations in fruit per plant among tomato varieties. This study also showed that the number of fruits per plant increased with increasing intra-row spacing. Accordingly, the maximum number of fruits per plant was obtained from 50cm spaced plants followed by 40cm which was statistically similar with the number of fruits obtained from 30cm intra-row spacing while the minimum was from 20cm spaced plants (Table 5). The total number of fruits per plant decreased as planting density increases, which could be due to the increased plant competition for growth resources in higher planting densities. These findings

agree with the report of Law-Ogbomo and Egharevba (2009); Ara *et al.* (2007); Sharma *et al.* (2001); Charlo *et al.* (2007); Balemi (2008) and Ebrahim and Ali (2013).

Fruit Weight

In the current study fruit weight was significantly influenced by both intra-row spacing and tomato varieties differences, though the interaction effect of the two main factors showed non-significant. The highest fruit weight (148.76 g) was recorded from variety Bishola followed by Fetan (Table 5). The existence of significant variations in fruit weight among tomato varieties is in agreement with the findings of Desalegn *et al.* (2016) and Davis and Estes (1993). In this study mean fruit weight also increased along with increasing in intra-row spacing. The maximum fruit weight was obtained from 50cm spaced plants while the minimum from 20cm which was statistically similar to the fruit weight obtained from 30cm and 40cm (Table 5). The increment of fruit weight with increasing intra-row spacing is to be due to lesser competition among neighbouring plants for nutrient, light, space and water resulting in better assimilates production and partitioning to fruits. Similarly, findings of Duguma (2000) and Davis and Estes (1993) confirmed higher average fruit weight at wider spacing as compared to closer spacing.

Total Fruit Yield

The analysis of variance of this study revealed significant total fruit yield differences among tomato varieties and intra-row spacing despite their interaction did not significantly influence the total fruit yield. The maximum total fruit yield was obtained from variety Fetan followed by Roma VF (Table 5). The difference might be due to the maximum number of clusters per plant, the number of fruits per cluster and the number of fruits per plant (Table 5). Current results are in line with the finding of Duguma (2000); Papadopoulos and Ormrod (1991); Desalegn *et al.* (2016) and Meseret *et al.* (2012). On the other hand, total fruit yield decreased with increasing intra-row spacing in which the maximum yield was obtained from 20cm intra-row spaced plants which were statistically similar with 30cm, while the minimum from 50cm intra-row spacing which was also statistically similar with the fruit yield of from 40cm intra-row spacing (Table 5). This result agrees with the report of Kirimi *et al.* (2011) and Muhammad and Singh (2007) who confirmed that too wide spacing decreased yield due to inefficient utilization of spaces, light and nutrients.

Table 5. The effect of intra-row spacing and tomato varieties on yield and yield components of tomato in the study conducted in Mizan-Aman during 2016/17 cropping season.

Treatment	Number of cluster/plants	Number of Fruit/cluster	Number of fruit/plants	Fruit Weight(g)	Total yield(t/ha)
			Variety		
Roma VF	7.32a	4.04a	26.5a	89.94c	33.88b
Bishola	5.52b	2.72b	14.8b	148.76a	28.67c
Fetan	8.63a	3.92a	26.1a	132.35b	39.73a
LSD(0.05)	1.69	0.4	1.9	8.96	1.39
			Intra-Row spacing(cm)		
20	5.76c	3.3	18.4c	115.44b	37.07a
30	6.56bc	3.46	21.5b	121.09b	36.09a
40	7.8b	3.57	23.5b	121.26b	32.36b
50	8.51a	3.89	26.4a	136.7a	30.87b
LSD (0.05)	1.95	NS	2.2	10.34	1.63
CV (%)	22.56	13.27	9.8	8.56	4.83

LSD(5%)= Least significant difference at P= 0.05, CV(%)= coefficient of variation in percent

Means with the same letter(s) within a column are not significantly different at 5% level of significance.

Quality Parameters

Marketable Fruit Yield

In the current study, the marketable tomato fruit yield was significantly different among varieties and intra-row spacing. Significantly higher marketable fruit yield was obtained from variety Fetan followed by Roma VF while the lowest was recorded from Bishola (Table 6). The differences among the varieties in marketable yield could be associated with inherent varietal differences. On the other hand, among the three varieties, Roma VF

exhibited relatively less attack by blight. Meseret *et al.* (2012) and Desalegn *et al.* (2016) have shown the differences among tomato varieties in marketable fruit yield. Marketable fruit yield of tomato in this study showed a reduction with increasing intra-row spacing. The maximum marketable yield was from 30cm intra-row spaced plants which were statistically similar to 20cm, while the minimum was from 50cm (Table 6). The higher marketable yield at narrower intra-row spacing is likely to be due to greater canopy cover which could protect the fruits from sun scalding that could reduce the fruit quality, as well as relatively more tomato fruit produced at the higher plant population per unit area. Similarly, (Ara *et al.*, 2007); Balemi (2008), and (Lemma and Yayeh, 2003) reported that Marketable yield increases as planting density increased.

Unmarketable Fruit Yield

On the other hand, the highest percent of unmarketable fruit yield (38.14%) was produced by variety Bishola, while the lowest (28.84%) by a variety of Roma VF (Table 6). The main cause for the higher unmarketable yield in variety Bishola and Fetan was associated with their susceptibility to blight disease for which variety Roma VF was less affected. Similarly, Desalegn *et al.* (2016) reported significant differences in unmarketable yield among tomato varieties, while Dessie (2015) also reported a significantly higher unmarketable fruit from Bishola and Fetan. On the other hand, maximum percent unmarketable yield (49.3%) were harvested from 50cm intra-row spaced plants, while the minimum (20.8%) from 30cm which was statistically similar with 20cm (Table 6). This shows that the unmarketable yield is usually related to sunburn, deformed shape, damage by birds and fruit cracking in which at higher plant population densities the fruits are covered by good foliage and protected from direct radiation that could enhance marketability. Similarly, this result confirmed the findings of; (Ara *et al.*, 2007), (Meseret *et al.*, 2012), Duguma (2000), Ara *et al*. (2007), (Balemi, 2008), and (Lemma and Yayeh, 2003), who reported that at densely populated plants produce minimum unmarketable yield than sparsely populated plants

Fruit Shape Index

The analysis of variance of this study also revealed significant fruit shape index differences among tomato varieties. Significantly higher fruit shape index (1.62) was obtained from variety Roma VF (Table 6) since fruit shape index in tomato is mainly related to inherent varietal characteristics as previously reported by (HabtamuT. and Dessalegn, 2015) indicating the existence of differences among tomato varieties in fruit shape index. According to Acedo *et al.* (2008) fruits having a flat shape with length less than the width (<1 length to width ratio) are considered as large fruits while oblong shape fruits with length greater than the width (>1 length to width ratio) as small fruits. The lowest fruit shape index showed that the increment in fruit size is proportional to both sides.

Pericarp Thickness

The analysis of variance showed a significant fruit pericarp thickness differences among tomato varieties. The maximum pericarp thickness was measured from variety Fetan which was statistically similar to Bishola, while the minimum was recorded from Roma VF (Table 6). The significant differences in the fruit pericarp thickness of tomato varieties are also in line with the findings of (HabtamuT. and Dessalegn, 2015) which confirms the existence of significant differences among tomato varieties in fruit pericarp thickness.

Total Soluble Solids

In the current study, intra-row spacing and varieties showed significant differences in total soluble solids (TSS) content of tomato. The TSS content of a variety of Roma VF was the highest but statistically similar to Fetan (Table 6). The difference in TSS among tomato varieties is in agreement with the findings of Tabasi *et al.* (2013), (HabtamuT. and Dessalegn, 2015). The TSS was also reduced along with decreasing intra-row spacing, in which the highest TSS was recorded from 50 cm intra-row spacing which was also statistically similar with 40 cm, (Table 6). The higher soluble solids in wider spacing are because more space between plants enhances photosynthesis resulting in increased soluble solids Tabasi *et al.* (2013).

Titratable Acidity

The analysis of variance of this study showed a significant fruit titratable acidity differences among tomato varieties. The highest titratable acidity was obtained from Bishola which was statistically similar to Roma VF (Table 6). The significant difference observed

in titratable acidity of the three varieties was also in line with the findings of (Ara *et al.*, 2007) and (Tigist, 2008) who stated that there are significant differences among tomato varieties in fruit titratable acidity.

Table 6. The effect of intra-raw spacing and varietal inherent characters some quality parameters of tomato in the study conducted in Mizan-Aman during 2016/17 cropping season.

Treatment	Marketable yield (t/ha)	Unmarketable yield (%)	Fruit shape Index	Pericarp thickness(cm)	pH	Titratable Acidity	Total soluble solids
Variety							
Roma VF	24.11b	28.84c	1.62a	0.57b	4.51a	0.72a	6.86a
Bishola	17.74c	38.14a	0.77c	0.60a	4.28b	0.73 a	6.12b
Fetan	26.34a	33.71b	0.99b	0.61a	4.48a	0.63b	6.66a
LSD(0.05)	2.25	2.39	0.92	0.043	0.11	0.062	0.41
Intra-Row spacing(cm)							
20	28.79a	22.32c	1.10	0.59	4.40	0.72	5.82b
30	28.94a	19.8c	1.13	0.61	4.34	0.65	6.24b
40	18.83b	41.82b	1.16	0.59	4.46	0.73	6.89a
50	15.65c	49.3a	1.12	0.60	4.50	0.67	7.13a
LSD (0.05)	0.25	2.76	NS	NS	NS	NS	0.47
CV (%)	4.25	8.42	9.57	8.5	2.77	10.56	7.5

LSD(5%)= Least significant difference at P= 0.05, CV(%)= coefficient of variation in percent
Means with the same letter(s) within a column are not significantly different at 5% level of significance.

Fruit pH-Value

Fruit pH was significantly different among tomato varieties in which the highest values were recorded from Roma VF, which was statistically similar to variety Fetan, (Table 6). Variation among tomato varieties in pH value of fruits conforms with the findings of HabtamuT. and Dessalegn (2015).

CONCLUSION AND RECOMMENDATIONS

This research revealed that intra-row spacing greatly affected plant growth and ultimately the final yield and quality of tomato. Among the varieties, Fetan was found to be better in total and marketable fruit yield as compared to the other two varieties. It was also early in flowering, fruiting and maturity. On the other hand, Roma VF was higher in total soluble solid and organic acid, which gives the variety better flavour than the others. The outcome of this study also confirmed that tomato variety Fetan matures earlier and provides higher total and marketable fruit yield that makes it suitable for Mizan-Aman area for production.

Although 20cm and 30cm intra-row spacing equally gave maximum total and marketable yield, 30cm spacing is to be favoured for the study area, since it requires relatively minimized planting material and easy for management due to its wider spacing. Thus, tomato variety Fetan and intra-row spacing 30cm could be used in Mizan-Aman area.

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REFERENCES

Acedo, A., C. Thanh and B. Borarin. 2008. Technological Developments for Freshand Processed Tomato and Chilli. Asian Vegetable Research and Development Center (AVRDC)(ed.) Training manual on postharvest research and technology development for tomato and chilli: 75-87.

Ara, N., M. K. Bashar, S. Begum and S. S. Kakon. 2007. Effect of spacing and stem pruning on the growth and yield of tomato. International Journal of Sustainable Crop Production, 2: 35-39.

Balemi, T. 2008. Response of tomato cultivars differing

in growth habit to nitrogen and phosphorus fertilizers and spacing on vertisol in Ethiopia. Acta agriculturae Slovenica, 91: 103-19.

Charlo, H. C. O., R. Castoldi, L. A. Ito, C. Fernandes and L. T. Braz. 2007. Productivity of Cherry Tomatoes under Protected Cultivation Carried out with Different Types of Pruning and Spacing. Acta Horticulturae: 323-26.

Davis, J. M. and E. A. Estes. 1993. Spacing and Pruning Affect Growth, Yield, and Economic Returns of Staked Fresh-market Tomatoes. Journal of the American Society for Horticultural Science, 118: 719-25.

Desalegn, R., T. Wakene and S. Addis. 2016. Tomato (Lycopersicon esculentum Mill.) varieties evaluation in Borana zone, Yabello district, southern Ethiopia. Journal of Plant Brreding and Crop, 8: 206-10.

Dessie, T. and Y. Jobre. 2004. A review of the importance and control of Newcastle disease in Ethiopia. Ethiopian Veterinary Journal, 8: 71-81.

Duguma, A. 2000. Variety and plant density influence on fruit yield and quality of processing types of tomatoes, A Master of Science thesis Duncan DB (1955). New Multiple Range and Multiple F-tests.

Ebrahim, M. and D. Ali. 2013. Plant spacing and cultivar affects yield components, qualitative traits and early ripening of tomato (Lycopersicon esculentum Mill). . Notulae Scientia Biologicae, 5: 494-98.

Gemechis, A. O., P. C. Struik and B. Emana. 2012. Tomato production in Ethiopia: constraints and opportunities International Research on Food Security, Natural Resource Management and Rural Development. Resilience of Agricultural Systems against Crises: Book of Abstracts.

Getahun, D. and D. Bikis. 2015. Responses of Tomato Varieties to Intra-row Spacing Under Rain-fed Production. Agricultural Science Research Journal, 5: 171-79.

HabtamuT., W. M. and Y. Dessalegn. 2015. Physicochemical attributes of Tomato (Lycopersicon esculentum Mill.) varieties under Polyhouse and Mulching Conditions. Mediterranean Journal of Biosciences, 1: 38-49.

Kirimi, J. K., F. M. Itulya and V. N. Mwaja. 2011. Effects of nitrogen and spacing on fruit yield of tomato. African Journal of Horticultural Science, 5: 50-60.

Law-Ogbomo, K. E. and R. K. A. Egharevba. 2009. Effects of planting density and NPK fertilizer application on yield and yield components of tomato (Lycospersicon esculentum Mill) in forest location. World Journal of Agricultural Sciences, 5: 152-58.

Lemma, D. and Z. Yayeh. 2003. Agronomic studies on tomato and capsicum. In: Helath E. and Lemma D,(Eds). Horticultural research and development in Ethiopia Proceedings of the Second Horticultural Workshop of Ethiopia, 1-3 December, 1992. Addis Ababa, Ethiopia. Ethiopia. pp. 153.

Meseret, D. R., M. Ali and B. Kassahun. 2012. Evaluation of tomato (Lycopersicon esculentum, Mill.) Genotypes for yield and yield components. . The African journal of plant science and Biotechnology, 6: 45-49.

Muhammad, A. and A. Singh. 2007. Intra-Row Spacing and Pruning Effects on Fresh Tomato Yield in Sudan Savanna of Nigeria. Journal of Plant Sciences, 2: 153-61.

Nego, J., K. Balcha and D. Belew. 2015. Evaluation of Tomato (Lycopersicon esculentum Mill.) Varieties for Seed Yield and Yield Components under Jimma Condition, South Western Ethiopia. Journal of Agronomy, 14: 292-97.

Papadopoulos, A. P. and D. P. Ormrod. 1991. Plant spacing effects on growth and development of the greenhouse tomato. Canadian Journal of Plant Science, 71: 297-304.

Regassa, D., W. Tigre and A. Shiferaw. 2016. Tomato (Lycopersicon esculentum Mill.) varieties evaluation in Borana zone, Yabello district, southern Ethiopia. Journal of Plant Breeding and Crop Science, 8: 206-10.

Seid, H., K. Merema and W. Mestawat. 2013. Effect of intra row spacing on the growth and development of tomato. International Journal of Sciences, 10: 19-24.

Sharma, D., D. Chaudhary and T. Verma. 2001. Growth and seed yield of tomato (Lycopersicon esculentum Mill) cv. Roma as influenced by levels of nitrogen and plant spacing. Haryana Journal of Horticultural Sciences, 30: 95-96.

Tabasi, A., H. Nemati and M. Akbari. 2013. The Effects of Planting Distances and Different Stages of Maturity on the Quality of Three Cultivars of Tomatoes (Lycopersicon esculentum Mill).

Notulae Scientia Biologicae, 5: 371-75.

Tigist, T. 2008. Evaluation of tomato (Lycopersicon esculentum Mill.) varieties for yield, physicochemical properties and storability under ambient conditionsHaramaya University, Ethiopia. pp. 36-75.