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Effect of Inter and Intra-Row Spacing on Yield and Yield Components of Tomato (Solanum lycopersicum Linn.) in South Tigray, Ethiopia

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Abstract
Tomato is one of the vegetables with its highest production in south Tigray and growers used as a source of income due to its cash value nature. A field experiment was conducted at Tumuga and Fala locations during 2012/2013 cropping season under irrigation condition. The objective was to determine the best inter and intra-row spacing for optimum yield and yield components of tomato. The treatment consisted of factorial combination of two inter-row spacings (50 and 100 cm) and three intra-row spacings (20 cm, 30 cm and 40cm) using Randomized Complete Block Design in a factorial arrangement(2x3) with three replications. The highest total and marketable fruit yield was obtained from 20 cm intra-row spacing with 50 cm inter row spacing. On the other hand, the lowest total and marketable fruit yield was obtained from the wider spacing of 40 cm intra-row with 100 cm inter-row spacing. The present result indicates that determinate tomato type can produce higher total and marketable fruit yield under narrowly spaced plants. From this study it could be concluded that appropriate inter and intra-row spacing with variety selection could be practiced to increase the yield and quality of tomato plant. Thus, Tomato (Roma VF variety) growers around the study area can be benefited if they use narrow spacing (20 cm intra and with 50 cm inter-row spacing).
Keywords: Tomato, intra-row spacing, inter-row spacing, yield

INTRODUCTION

Tomato (*Solanum lycopersicum* Linn.) belongs to the *Solanaceae* family. The center of origin for the world tomato is considered to be Andean zone, whereas it is considered that the tomato was domesticated in Mexico, and that the name of tomato was derived from the 'tomatil' in the Nahua tongue of Mexico (Ara *et al.*, 2007). Presently, tomato is one of the vegetables with the highest production in the world and its production is increasing all over the world, primarily, in Asia. The production area in Europe, north and Latin America tends to stop increasing but the production is sustained by the increase of yield per hectare, probably using high yielding varieties and other improved agronomic practices (Zhang, 2010).

The importance of tomato as a vegetable crop is reflected in its large-scale cultivation in the world. Tomato is grown on about 4.5 million hectares worldwide, the largest producer being China with 32 million metric tons. India produces about 7.6 million metric tons of tomatoes from about 540,000 ha (Daniel, 2007). Now-a-days tomato is grown in most of the countries around the globe except the colder region. It can be grown on a small scale in the kitchen garden, where a few plants yielding fruits for the whole family and a commercial scale as a cash crop by the vegetable growers (David, 2010).

Tomato is among the most important vegetable crops in Ethiopia. Both fresh and processed tomato varieties are popular and economically important vegetable crops produced in the country (Geleta *et al*., 1995). The total production of this crop in the country has shown a marked increase (Lemma *et al.,* 2003) since it became the most profitable crop providing a higher income to small scale farmers compared to other vegetable crops. However, tomato production is highly constrained by several factors especially in developing nations like Ethiopia.

The national average of tomato fruit yield under farmers' condition is 9 t/ha, which is very low compared to 25 and 40 t/ha at demonstration and experimental research plots, respectively (Lemma, 2002). Increasing production of the crop has a great role to strengthen the growing vegetable industries in the country. However, the production and productivity of the crop in the country is influenced by different factors. Lemma *et al.* (2003) reported 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 in addition yield variation in tomato may also be occurred due to disease infestation, lack of improved variety and variation in cultural practices like plant population per given area.

Plant spacing is the most important factor that affects yield and fruit quality of tomato (Tesfaye, 2008). In Ethiopia, so far plant spacing was determined for tomatoes only at Melkassa research center, moreover, such study was done in tomatoes under vertisol condition and the whole of such previous agronomic studies were confined only to sandy loam soils of the rift valley regions of the country. Accordingly, farmers get lower yield

mainly due to inappropriate agronomic practices and lack of improved variety. Improper plant spacing is among the notable reasons of low productivity tomato. Plant spacing greatly influenced growth, yield, and quality parameters both in fresh market and processing tomatoes. Additionally, understanding the variability of varietal response to different plant spacing is crucial in improving the tomato fruit yield and quality. This study was therefore, conducted with the objective to determine the best inter and intra-row spacings for optimum yield and yield components of tomato.

MATERIALS AND METHODS

Description of the Study Area:

Table 1. Description of the study areas

Testing site	Latitude and longitude	Elevation (m)	Temperature (^oC)		Mean annual rainfall (mm)	Soil type
			Min	Max		
Tumuga	12^0 23' 23'' N and 39^0 36' 12'' E	1459	12.4	28.7	675.1	Sandy-loam
Fala	12^0 31' N and 39^0 36' E	2100	11.71	26.36	716.5	Sandy-loam

Experimental Design and Treatments Arrangements

The experiment was laid out in 2 x 3 factorial arrangements. Factor one: inter-row spacing with two levels (50 and 100 cm) and factor two: intra-row spacing with three levels (20, 30 and 40 cm) was used randomized complete block design (RCBD) with three replications (Table. 2). The area of each experimental plot was 18 m^2 (3.6 m width and 5 m length) and 9.6 m^2 (2.4m width and 4 m length) at Tumuga and Fala sites, respectively. Each plot contained different number of seedlings depending on the inter and intra-row spacing capacity in order to obtain specified number of plants per plot.

Table 2. Details of the Treatment Combinations

Treatments	Inter-row spacing (cm)	Intra-row spacing (cm)	Treatment combinations
1	50	20	50 X 20 cm
2	50	30	50 X 30 cm
3	50	40	50 X 40 cm
4	100	20	100 X 20 cm
5	100	30	100 X 30 cm
6	100	40	100 X 40 cm

Experimental Procedures

Tomato variety (Roma-VF) was sown in 15 cm row spacing on well prepared seed bed of 1m x 5 m nursery area. The seed was covered with light soil and mulching grasses until emergence to protect seeds from washing away during watering. Beds were watered with watering can followed by surface irrigation and proper management (weeding, watering) practices were followed to produce healthy and vigorous seedlings. Land preparation was practiced in advance for better seedling establishment and to expose the soil to solar treatments that could be useful to reduce diseases and insect pest incidence. Seedlings were hardened before transplanting to the field for enable them withstand the experimental field conditions.

Healthy and uniform seedlings with 3 to 4 leaf number were transplanted at the age of 30 days after sowing. The seedlings were irrigated after transplanting. Inorganic fertilizers, diammonium phosphate (DAP) and urea were applied to each plot at the rate of 115 kg/ha P_2O_5 and 92 kg/ha N, respectively. The whole amount of phosphorus fertilizer was applied at transplanting, whereas half rate of nitrogen was applied during transplanting and remaining was applied at flowering stage of the plant.

DATA ANALYSIS

Yield and yield component parameters were recorded and analyzed using GenStat version16 computer software.

RESULTS AND DISCUSSION

Total fruit yield of tomato variety (t/ha)

A significant ($p<0.05$) interaction effect of inter-row spacing with intra-row spacing was observed on total fruit yield (Table 3) at both locations. Maximum and significantly different fruit yield (45.52 and 50.65 t/ha) were obtained from the treatment combination of 50 cm inter-row with 20 cm intra-row spacings at Tumuga and Fala

locations respectively. While, the lowest total fruit yield (13.9 and 27.92 t/ha) was recorded from wider spacing of 100 cm inter-row with 40 cm intra-row spacing at Tumuga and Fala, respectively. This study clearly indicated that short set (determinant) tomato types increased their yield potential at narrow spacing as compared to wider spacings.

In line with this study, Rafi, (1996), Myanmar, (1999) and Zhang, (1999) reported that the highest number of fruits per plant and per hectare was obtained from higher plant density than widely spaced plants of tomato crop. In contrast to this study, Tesfaye (2008) reported no interaction effect between variety and intra-row spacing in terms of influencing total fruit yield of tomato at wider spacing.

Marketable Fruit Yield of Tomato Variety (t/ha)

At two locations, Tumuga and Fala, a significant ($p<0.05$) interaction effect of inter-row spacing with intra-row spacing was observed on marketable fruit yield (Table 3). The highest and significantly different marketable fruit yield (45.40 and 50.03 t/ha) was obtained from the treatment combination of 50 cm inter-row with 20 cm intra-row spacing at Tumuga and Fala sites in that order. However, the lowest marketable fruit yield (10.49 and 27.72 t/ha) was recorded at wider spacing of 100 cm inter-row with 40 cm intra-row spacing at Tumuga and Fala, respectively.

The highest marketable yield recorded at closer spacing is attributed to more tomato fruit produced at the higher plant population per hectare. The higher marketable yield at narrow plant spacing could be due to greater canopy and growth habit of determinate tomato type like Roma-VF which could be protected the fruits from sun scalding, thereby contributed to production of damage free fruit. Hence, unmarketable fruit yield is minimized than the plants planted at wider spacing. This result is in line with Lemma *et al.* (2003), he reported that, the highest marketable pepper pod yield (20.09 qt /ha) at Bako and (15.57 qt/ha) at Didesa planted at closer spacing of 20 cm between plants. In contrast, Uddin *et al.* (1997) reported that wider spacing with cultivars interaction gave higher marketable tomato fruit yield (82.39 t/ha).

Unmarketable Fruit Yield of Tomato Variety (t/ha)

The interaction effect of inter and intra-row spacing showed significant ($p<0.05$) difference on unmarketable fruit yield at Fala site. However, the effect of inter-row spacing, intra-row spacing as well as their interaction showed no significant ($P>0.05$) effect on unmarketable fruit yield at Tumuga site. The highest and significantly different unmarketable fruit yield (0.617 t/ha) at Fala site was recorded from the treatment combination of 50 cm inter-row with 20 cm intra-row spacing. On the other hand, the lowest unmarketable fruit yield (0.1985 t/ha) was recorded from the treatment combination of 100 cm inter-row with 40 cm intra-row spacing. This result indicated that the highest unmarketable fruit yield per hectare was recorded from the narrow inter and intra-row spacing. The highest unmarketable fruit yield at the narrow spacing was due to high number of plants per unit area.

Table 3.Means for interaction effect of inter and intra-row spacing on total, marketable and unmarketable yield of Tomato (t/ha)

Inter-row spacing (cm)	Intra-row spacing (cm)	Total yield /ha		Mark yield /ha		Unmark yield t/ha
		Tumuga	Fala	Tumuga	Fala	Fala
50 cm	20 cm	45.52^{a}	50.65^{a}	45.40 ^{a}	50.03^{a}	0.617^{a}
50 cm	30 cm	38.0.3^{b}	45.88^{b}	35.79 ^{b}	45.4^{b}	0.476^{b}
50 cm	40 cm	36.37^{b}	40.15^{c}	34.56 ^{b}	39.77^{c}	0.379^{c}
100 cm	20 cm	26.72^{c}	35.34^{d}	23.41 ^{c}	35.08^{d}	0.25^{de}
100 cm	30 cm	22.50^{c}	37.32^{cd}	20.32 ^{c}	37.02^{cd}	0.298^{d}
100 cm	40 cm	13.90^{d}	27.92^{e}	10.49 ^{d}	27.72^{e}	0.1985^{e}
LSD (5%)		6.779	3.617	3.287	3.639	0.073
CV (%)		12.3	5.0	6.4	5.1	10.9

Means followed by the same letter within the same column are not significantly different at 5% level of significance.

Average Fruit Length of Tomato Variety (cm)

Intra-row spacing showed a significant (P<0.05) effect on fruit length. However, the main effect of inter-row spacing and its interaction with intra-row spacing showed non-significant difference on average fruit length. The highest fruit length (6.957 and 6.718 cm) was recorded from 40 cm intra-row spacing at Fala and Tumuga respectively whereas, the lowest (5.619 and 5.983 cm) fruit length was recorded from the narrow spacing of 20 cm intra-row spacing at Fala and Tumuga respectively.

Table 4. Means for intra-row spacing effect on fruit length of tomato

Treatments	Fruit Length (cm)	
Intra-row spacing	Tumuga	Fala
20 cm	5.619[b]	5.983[b]
30 cm	6.380[a]	6.627[ab]
40 cm	6.718[a]	6.957[a]
Grand mean	6.24	6.52
LSD (5%)	8.0	8.6
CV (%)	0.921	1.026

Means followed by the same letter within the same column are not significantly different at 5% level of significance.

Average Fruit Diameter of Tomato Variety (cm)

Interaction effect of inter and intra-row spacing showed significant (P<0.05) effect on average fruit diameter. As the inter-row spacing increases from 50 cm to 100 cm and intra-row spacing increases from 20 cm to 40 cm, average fruit diameter increases from 3.347 to 4.047 and 3.270 to 4.20 cm at Fala and Tumuga, respectively. The highest average fruit diameter (4.047 and 4.20 cm) was recorded from the wider spacing of 100 cm between rows with 40 cm between plant spacing. However, it was not significantly different from the treatment combination of 50 cm inter-row spacing with 30 cm intra-row spacing. On the other hand, the lowest average fruit diameter (3.347 and 3.270 cm) was recorded from the treatment combination of 50 cm inter-row with 20 cm intra-row spacing.

Table 4. Means for interaction effect of inter and intra-row spacing on average fruit diameter of tomato.

Inter-row spacing (cm)	Intra-row spacing (cm)	Average fruit diameter (cm)	
		Falla	Tumuga
50 cm	20 cm	3.347 [d]	3.270 [b]
50 cm	30 cm	3.860[ab]	3.760 [ab]
50 cm	40 cm	3.700 [bc]	3.567[b]
100 cm	20 cm	3.673 [bc]	3.563[b]
100 cm	30 cm	3.587 [c]	3.490[b]
100 cm	40 cm	4.047 [a]	4.200[a]
Grand mean		3.702	3.642
LSD (5%)		3.4	7.9
CV (%)		0.2259	0.5267

Means followed by the same letter within the same column are not significantly different at 5% level of significance.

CONCLUSION

Tomato is among the most important vegetable crops in Ethiopia in general and southern zone of Tigray in particular. However, tomato production in Ethiopia and Southern zone of Tigray is highly constrained by several factors. Farmers get lower yield mainly due to in appropriate agronomic practices and lack of improved variety. Improper plant spacing is among the notable reasons of low productivity of this crop. Plant spacing greatly influenced growth, yield, and quality parameters both in fresh market and processing tomatoes.

Selections of best inter and intra-row spacing helps to utilize the small land efficiently and intensively. Having this scenario in mind, this study was conducted to investigate the effect of inter-row and intra-row spacing on yield and yield component of tomato. The highest total and marketable fruit yield per hectare was obtained from the treatment combination of 20 cm intra-row spacing with 50 cm inter row spacing. On the other hand, the lowest total and marketable fruit yield per hectare was recorded from the wider spacing (from

treatment combination of 40 cm intra-row with 100 cm inter-row spacing). This result indicates that the determinate tomato type produces highest total and marketable fruit yield even under highly populated plants.

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