

Influence of Inter and Intra-rows Spacing on Yield and Yield Components of Tomato Cultivars

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አገፅርተ-ጥናት

ቲማቲም በኢትዮጵያ በተለይም በመካከለኛው ስምጥ ሸለቆ አካባቢ በስፋት በመመረት ለአርሶ አደሩ በገቢ ምንጭነት እያገለገለ ይገኛል። በአሁኑ ጊዜ በመስመርና በተክሉ መሀከል ያለው የመትኪያ ርቀት በቲማቲም አምራች አርሶ አደሮች እየተተገበረ ያለው ምርምር ካሳወቀው የመትኪያ ርቀት ይለያል። ስለሆነም ይህንን በመረዳት በመልካሳ ምርምር ማዕከል በ2004 እና 2005 ዓ.ም. በተክልና በረድፍ መካከል ያለው ርቀት በምርትና በምርት አካል ላይ ያለው ተፅዕኖ ተፈትሻል። ውጤቱን ለማየት በተክሎች መካከል ያሉ የተለያዩ ርቀቶች (20, 30 and 40 ሳ.ሜ.)፤ በረድፎች መካከል ያለ ርቀት (70, 80, 90 and 100 ሳ.ሜ.)ና ሁለት የቲማቲም ዝርያዎች ማለትም ለኢንዱስቲሪ ግብአት የሚውልና የገቢታ ዝርያን በማቀናጀት ተሞክሯል። የተወሰዱ መረጃዎች የተክሉ የቅርንጫፍ ስፋት፣ ከመሬት በላይ ያለ የደረቀ የተክሉ ጠቅላላ ክብደት፣ እንዲሁም ጥቅም ላይ የሚውል እና የሚይውል የፍሬ ምርት፣ የፍሬው ወርድ እና ርዝመት እንዲሁም የፍሬው የስኳር መጠን በመውሰድና በማገናዘብ የመተንተን ስራ ተከናውናል። ለገቢታ የሚውለው ዝርያ ከፍተኛ የሆነ የቅርንጫፍ ርዝመት 40 ሳ.ሜ በ100 ሳ.ሜ ሲያስመዘግብ ለኢንዱስትሪ ግብአትነት የሚያገለግለው ዝርያ ደግሞ በ40 ሳ.ሜ. በ90 ሳ.ሜ አስመዘግቧል። እንዲሁም ከፍተኛ የስኳር መጠን የተመዘገበው በ40 ሳ.ሜ. የተክሎች ርቀት ሲሆን ነገር ግን ከ30 ሳ.ሜ. የላቀ ልዩነት አልነበረውም። ከፍተኛ የሆነ የፍሬ ምርት የተገኘው በጠበበ ተክሎች መካከል ባለው ርቀት 20 ሳ.ሜ (100.45 ቶን በሄክታር)ና በረድፍ ርቀት 70 ሳ.ሜ.(92.55 ቶን/ሄክታር) ቢሆንም ከፍተኛ የሆነ ጥቅም ላይ የሚውል የፍሬ ምርት የተገኘው 90 ሳ.ሜ. (51.48 ቶን በሄክታር) ረድፍ ርቀትና 30 ሳ.ሜ. (45.78 ቶን በሄክታር) በተክሎች መካከል ባለ ርቀት ሲሆን ከ40 ሳ.ሜ. ጋር የላቀ ልዩነት አልነበረውም። ስለሆነም ድጋፍ ሳይጠቀሙ በቦይ የመስኖ የማምረት ዘዴ ለሚከተሉት አካባቢዎች ለሁለቱም ዝርያዎች ከፍተኛ ጥቅም ላይ የሚውልና ጥራት ያለው ቲማቲም ለማምረት 30 ሳ.ሜ በ90 ሳ.ሜ ወይም 40 ሳ.ሜ በ90 ሳ.ሜ በመልካሳና ተመሳሳይ ሥነ-ምህዳር ላላቸው አካባቢዎች ለማምረት መጠቀም ይቻላል።

Abstract

Tomato is an important cash crop in Central Rift Valley of Ethiopia and currently plant spacing practiced by growers quite different from research recommendation. Field experiment was carried out at Melkassa Agricultural Research Center, in the year

2011/12 and 2012/13 off seasons with the objectives of evaluating the effect of four inter-row spacings (70, 80, 90, and 100 cm) and three intra-row spacing (20, 30 and 40 cm) on yield and yield components of fresh market (Bishola) and processing (Cochoro) tomato cultivars. The treatments were arranged in 2x4x3 factorial in a split-split plot design in three replications. Data were collected on plant canopy width, above ground dry biomass as well total, marketable and unmarketable fruit yield and on quality parameters such as TSS, fruit length and diameter were analyzed. The results indicated that inter and inter-row spacing had a significant effect on plan canopy width, above ground dry biomass, total, marketable, unmarketable fruit yield, TSS, fruit length and diameter. The highest canopy width of Bishola (77.08 cm) was recorded at 40 cm x 100 cm whereas for Cochoro (71.30 cm) at 40 cm x 90 cm. Maximum fruit TSS (3.72) was recorded at 40 cm intra-row spacing and this was not significantly different from 30 cm (3.68). The highest total fruit yield of 100.45 and 92.55 ton/ha were recorded for closer inter and intra-row spacing of 70 and 20 cm, respectively. However, the highest marketable yield was obtained at 90 cm (51.48 ton/ha) inter-row spacing and at 30 cm (45.78 ton/ha) intra row spacing and this was not significantly different from 40 cm. The study suggest that 30 cm x 90 cm or 40 cm x 90 cm intra-inter row spacing combination was suitable for obtaining higher marketable yield and good quality fruit around Melkassa and similar conditions in Ethiopia.

Introduction

Like any other crops tomato fruit yield is a complex character that is influenced by many factors including genetic, agronomic and environmental factors (Ara *et al.*, 2007). Poor varietal performance and management practices that include inter and intra-row spacing among the major constraints of tomato production and productivity in Ethiopia.

Inter and intra row spacing is important agricultural factor and has great effect on fruit yield and yield components of tomato plant (Law-ogbomo and Egharevba, 2008). It is the one which choosing appropriate inter and intra row spacing especially in under open field production condition and it helps in efficient use of available resources such as water, light and soil nutrients (Law-ogbomo and Egharevba, 2009).

Plant spacing studies conducted at Melkassa Agricultural Research Center with the two recommended fresh market cultivars Marglobe and Heinz 1350 indicted a recommendation of 30 cm x 100 cm intra and inter-row spacing (Lemma, 2002). Nevertheless, field observation and personal communications in the rift valley belt showed that the current spacing practiced by growers quite different from research recommendation; there are also variations between growers for cultivar(s); some farmers in the Rift Valley use spacing of 70 and 100 cm between rows and 20 and 40 cm between plants for both fresh market and processing tomato cultivars.

To fill these gaps studies were conducted by Geremew *et al.* (2010) who recommended 40 cm inter row and 30 cm intra row spacing whereas Menberu *et al.* (2012), recommended 30 cm x 70 cm spacing for higher marketable yield; nevertheless, their studies did not consider inter and intra row spacing practices of growers.

The results of many studies have also shown that spacing altered the plant architecture, photosynthetic efficiency of leaves, fruit size and fruit production pattern. According to Heuvelink *et al.* (2009), both too narrow and too wide spacing do affect crops yield through competition and shading effect. So it is imperative to develop inter and intra row-spacing recommendation which may help the tomato plant to utilize resources more effectively and efficiently towards increased production, productivity and fruit quality (Ara *et al.*, 2007).

Systematic investigation of different spacing combination is very important to come up with relevant recommendation that will help growers to increase the yield and quality of different tomato cultivars for different purposes. Hence, the objective of this study was to determine the influence of inter-and intra-row spacing on yield and yield components of fresh market and processing tomato cultivars under open field conditions.

Materials and Methods

The experiment was conducted at Melkassa Agricultural Research Center (MARC), in 2011/12 and 2012/13 off season using furrow irrigation. Two tomato cultivars fresh market (Bishola) and processing (Cochoro) was compared in four inter-row spacing (100, 90, 80 and 70 cm) and three intra-row spacing (20 cm, 30 cm and 40 cm). The treatments were arranged in 2x4x3 factorial combination laid out in split-split plot design with three replications where, cultivars were assigned as main plot, inter-row spacing to the sub plots and spacing between plants as sub-sub plot for two seasons in a plot size of 24 m² (4 m x 6 m) using recommended spacing of 100 cm x 30 cm as a control. The seeds of both cultivars were obtained from vegetable research department of MARC. The seedlings were raised 1m x5m of seed bed and properly managed as MARC recommendation and healthy and uniform, seedlings were transplanted at 30 days after sowing; at 2-3 leaves stages of growth.

The experimental field was ploughed, harrowed and levelled to facilitate transplanting operation. Trial was fertilized with DAP (18 % N and 46 % P₂O₅) at the rate of 200 kg/ha at transplanting as band application and 100 kg/ha Urea (46 % N) was side dressed in split application of 50 kg/ha in 15 days after 50 kg/ha at transplanting and second (50 kg/ha) at flowering stage at (48 days) of transplanting. Furrow irrigation was practiced every four days in the first three weeks then after five days intervals. In the experimental field Selecron® 720 EC at a rate of 0.75 lit/ha; Ridomil® MZ at the rate of 2.5 kg/ha were sprayed every fifteen days for controlling insect pests and fungal diseases, respectively; moreover, Cruzeat 2.5 kg/ha for controlling bacterial disease

were applied two times during the growing period and other cultural practices were applied, when it was necessary.

Data on plant canopy width, above ground dry biomass as well total, marketable and unmarketable fruit yield were measured from five randomly selected plants per plot. Some of the yield components parameters such as TSS, fruit length and diameter were measured from sample fruits using refractometer and digital callipers, respectively. Disorders result from a combination of environmental, production and handling procedures were taken as unmarketable yield. The fruits were harvested at turning stage for fresh market and at red-ripe stage for processing type.

Data were subjected to analysis using SAS analytical software (SAS 9.2). Combined analyses were made according to (Gomez and Gomez, 1984). When the F-value was significant, a multiple means comparisons were performed using LSD at a P-value of 0.05.

Results and Discussion

Plant canopy width

The interaction effect of cultivar, inter and intra-row spacing for canopy width was highly significant (fig.1). The canopy width of Bishola and Cochoro cultivars increased with increasing in intra and inter-row spacing, though it varied in relation to cultivars, inter and intra row spacing. The highest canopy width of Bishola (77.08 cm) was recorded at 40 x 100 cm while for Cochoro (71.30 cm) at 40 cm x 90 cm, and the lowest canopy width of Bishola (46.64 cm) was recorded at 20 x 70 cm whereas Cochoro (43.03 cm) at 30 x 70 cm spacing.

The plant canopy width reflects the growth behaviour of a crop, related to genetic characteristics and environmental conditions under which it is growing (Comstock *et al.*, 2005). In this study both cultivars responded differently to the same range of inter and intra-row spacing. This result was in agreement with the findings of Ahmed *et al.* (2000) who concluded that closer spacing resulted in poor canopy growth as compared to the wider spacing and cultivars were not responding the same way to the same spacing due to difference in sensitivity to narrow spacing. In similar study with potato, Tesfaye *et al.* (2012) reported that canopy width of potato increased at wider spacing; due to minimum competition for resources between plants compared to closer spacing. Canopy width is important to determine plant spacing for its contribution to total amount of light that plant intercepts for photosynthesis efficiency of tomato Fenget *al.* (2010).

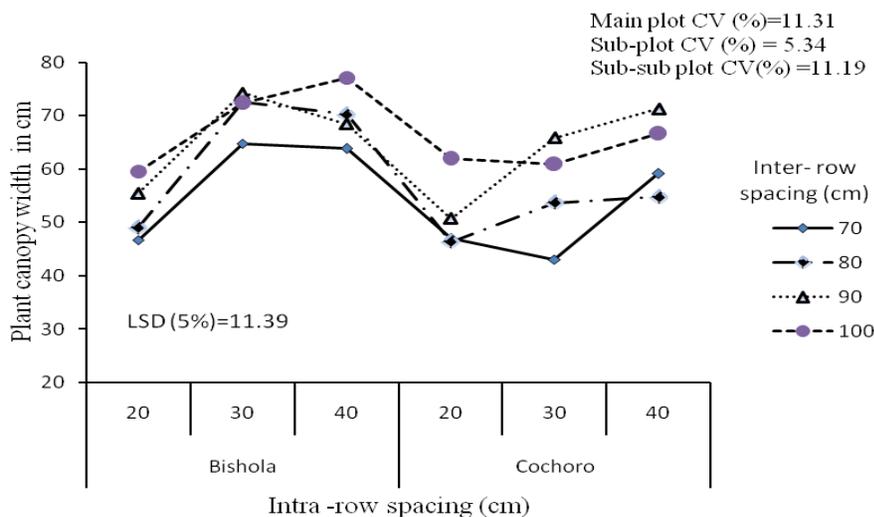


Figure: 1. Plant canopy width of tomato cultivars affected by interaction effects of cultivar, inter and intra-row spacing

Above ground dry biomass:

The above ground dry biomass per hectare was significantly affected by interaction effect of inter and intra-row spacing (Fig-2). The highest above ground dry biomass (10.71 ton/ha) was recorded at 20 cm x 80 cm, followed by 20 x 70 cm and this was not significantly different. Whereas the lowest above ground dry biomass (7.75 t/ha) was recorded at spacing combination of 40 x 100 cm for both cultivars. In most case, the result showed that above ground dry biomass decreased for wider inter and intra-row spacing combination levels, but at different rate. As Inter-row spacing increased from 70 cm to 80 cm the mean dry biomass yield was significantly increased at 20 cm intra-row spacing by 14.67%. However, further increasing in inter-row spacing from 80 cm to 100 cm the biomass yield decreased by 13.81%. Whereas at 30 cm intra-row spacing, biomass decreased by 21.27 % when inter-row spacing increased from 70 cm to 90 cm. Nevertheless, at 40 cm intra-row spacing biomass yield did not significantly differ for all inter row spacing except for 100 cm inter-row spacing which showed slight increase.

This result was in accordance with Ganesan and Subbiah (2004) and Heuvelink et al.(2009), who also reported that number of plants per unit area increased a greater biological yield was obtained due to increased in leaf area index enabled plants better utilization of solar radiation which favoured the maximum rate at which leaves are able to fix carbon during photosynthesis per unit area. However, in this study dry biomass increased up to some upper limit of inter and intra row spacing combination and then started to decline by further reducing inter and intra row spacing. Similarly, Nesmith (1993) also reported on water melon the above ground biomass increase up to some upper limit or threshold density, after which further increasing in plant number per

unit area by decreasing inter and intra-row spacing either maintain the same biological yield or cause decline.

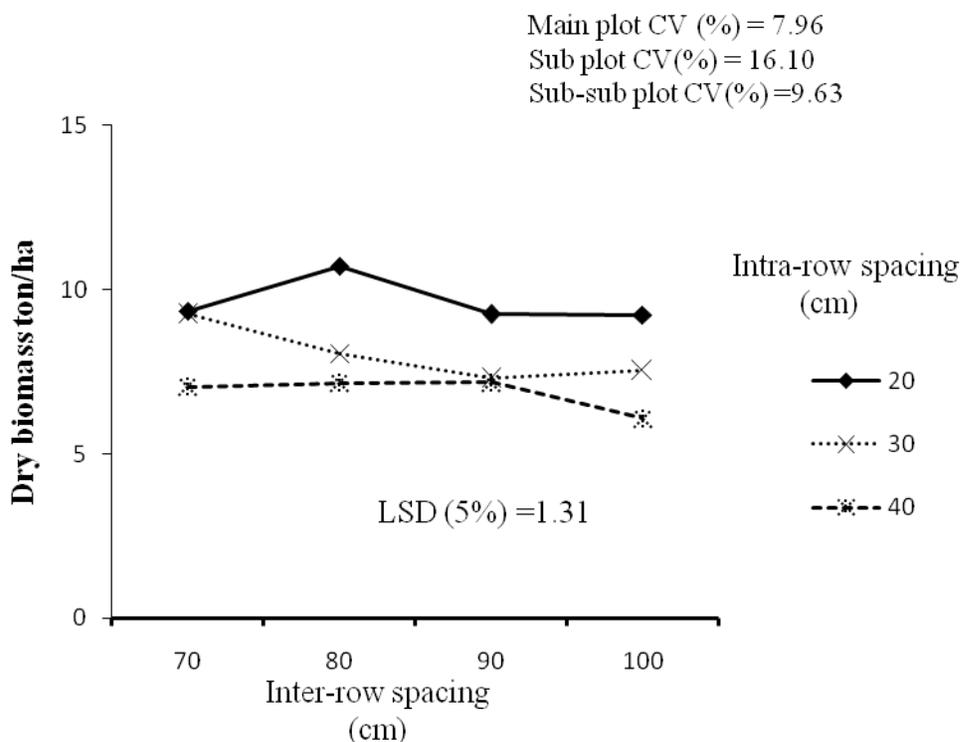


Figure2: Above ground dry biomass yield as affected by the interaction effects of inter and intra-row spacings of tomato cultivars

Yield parameter

Total yield:

The main effect of inter and intra row spacings exhibited statistically significant differences for total fruit yield (Table: 1) and the highest total fruit yield (100.45ton/ha)was obtained at 70cm, whereas the lowest total fruit yield (71.41 ton/ha) was obtained at 100 cm inter-row spacing. Intra row spacing had as well a significant effect and the highest total fruit yield (92.55 t/ha) was recorded at 20cm, whereas the lowest (74.53 t/ha) was obtained at 40 cm inter row spacing. All the interaction did not affect total fruit yield at ($P>0.05$) significant level.

The result in agreement with the findings of Maboko *et al.* (2011) and Law-ogbomosho and Egharevba (2009) who reported that total yield per hectare increased with the higher plant density per unit area. Similar result was reported by Tesfaye (2008) who reported the highest total fruit yield of potato cultivars was obtained at closer spacing of which higher plant population per unit area. Unlike this finding, Geremew *et al.* (2010), reported that increasing either interior intra-row spacing had no significant effect on total yield of tomato at Adamitulu.

Marketable

The main effect of interrow spacing had a significant effect on marketable fruit yield of the two cultivars (Table: 1) and the highest (51.48 ton/ ha) and lowest (32.06 t/ha) marketable yield of inter-row spacing were recorded at 90 cm and 70 cm, respectively. Intra row spacing had also a highly significant effect on marketable fruit yield, and the highest (45.78 t/ha) marketable fruit yield was obtained for intra row spacing of 30 cm and was not significantly different with 40 cm (42.26 ton/ha) and the lowest was recorded at 20 cm (Table.1). All interaction effect were non-significant ($P > 0.05$).

Ara *et al.* (2007) and Law-ogbomo and Egharevba (2009), also reported the highest marketable fruit yield was recorded at wider spacing than at narrow spacing, which supports the present finding. However, in this study increasing inter-row spacing from 90 to 100 cm, significantly reduce the marketable yield; due to sunburn that resulted from the exposure of fruits directly to sunlight at wider spacing. As opposed to this result, Geremew *et al.* (2010) concluded that variation of inter-row spacing had no effect on marketable fruit yield of tomato cultivars.

Unmarketable: Inter-row spacing had a highly significant effect on unmarketable yield of tomato cultivars (Table: 1) and the highest unmarketable yield (67.13 ton/ha) was recorded at inter-row spacing of 70 cm, whereas the lowest unmarketable yield (25.35 ton/ha) was obtained at wider inter-row spacing of 100 cm followed by 90 cm and this was not significantly different. Intra-row spacing had also a highly significant effect and the highest unmarketable fruit yield of (50.91 ton/ha) was recorded at 20 cm, whereas the lowest (32.27 t/ha) was produced at 40 cm intra-row spacing (Table 1). All interaction effects were non-significant ($P > 0.05$). Even though there was no significant ($P > 0.05$) difference in unmarketable yield between the cultivars, high percentage of unmarketable yield were recorded in both cultivars.

The major factors that caused high unmarketable yield were genetic characteristics of cultivars, decay, disease and insects attack in which some of the factors had more pronounced effect at narrow spacing. When inter and intra-row spacing became narrow it became difficult to apply different management practices such as chemical spray, weeding and also created favourable conditions for diseases and insect pests attack and cause high fruit rot loss due to closed up of canopy. Moreover, when inter row spacing became narrow the spaces taken by the plant became narrower and resulted in

computation between plants for light resulted in etiolation followed by plant lodging so that during furrow irrigation plants directly contact with water which resulted in fruit decay. Similarly, Kirimi *et al.* (2011) and Menberu *et al.* (2012) also reported that unmarketable yield of tomato fruit increased with decreased of plant spacing on tomato.

Table 1: Yield of tomato (t/ha) as affected by cultivar, inter and intra row spacing

Treatment Cultivars	Yield t/ha			TSS (°Brix)
	Marketable	Unmarketable	Total	
Bishola	43.07 ^{ns}	41.57 ^{ns}	85.05 ^{ns}	3.34 ^b
Cochoro	42.96 ^{ns}	40.85 ^{ns}	83.81 ^{ns}	4.00 ^a
LSD (5%)	3.03	3.27	4.49	0.32
Main plot CV (%)	15.57	21.34	15.46	8.74
Inter-row spacing (cm)				
70	32.47 ^c	67.13 ^a	100.45 ^a	3.67 ^{ns}
80	42.06 ^b	44.41 ^b	86.47 ^b	3.73 ^{ns}
90	51.48 ^a	27.96 ^c	79.45 ^c	3.68 ^{ns}
100	46.06 ^b	25.35 ^c	71.41 ^d	3.59 ^{ns}
LSD (5%)	4.2	6.52	6.36	Ns
Sub-plot CV (%)	15.52	21.77	13.96	6.30
Intra- row spacing (cm)				
20	41.01 ^a	50.91 ^a	92.55 ^a	3.59 ^b
30	45.78 ^b	40.46 ^b	86.25 ^b	3.68 ^{ab}
40	42.26 ^{ab}	32.27 ^c	74.53 ^c	3.72 ^a
LSD (5%)	3.72	4.01	5.5	0.092
Sub-sub plot CV (%)	14.42	17.47	10.78	4.29

Total soluble solids (°Brix)

Variety had a significant difference on mean total soluble solid (TSS) content of fruits. Highest TSS (4.00) was recorded for Cochoro (processing) followed by the fresh market Bishola (3.34). Moreover, highly significant difference in TSS was observed among intra-row spacing and the highest TSS (3.72) was recorded at 40 cm intra-row spacing and it was not significantly different from 30 cm (3.68), whereas the lowest (3.59) was obtained at 20 cm inter-row spacing. Lemma (2002) reported that processing type tomato has comparatively higher TSS than fresh market types; moreover according to Kirimi *et al.* (2011) higher TSS obtained at widerspacing might be due to translocation of assimilates (a major constituent of TSS) affected by growing conditions through the rate of assimilate export from the leaves.

Fruit length and diameter

Fruit length was significantly affected by interaction effects of inter and intra-row spacing and the highest (49.4 mm) and the lowest (36.74 mm) fruit lengths were recorded at inter and intra-row spacing combination of 40 cm x100 cm and 20 cm x 80

cm, respectively. Fruit length increased at different rate when intra-row spacing increased from 20 cm to 40 cm while jointed with 70 cm or 80 cm or 90 cm and 100 cm inter-row levels, but with different rate (fig-3). Fruit diameter was also significantly affected by interaction effect of cultivar and intra-row spacing (Fig.4). The highest fruit diameter for Cochoro (37.2 mm) and Bishola (51.9 mm) while the lowest for Cochoro (34.63 mm) and Bishola (40.17 mm) was recorded at 40 cm and 20 cm intra-row spacing, respectively. Cultivar Bishola was more responsive to increased intra-row spacing than Cochoro over the same range this might be due to genetic differences between cultivars. Fruit length and diameter determines the consumer preference in tomato crop.

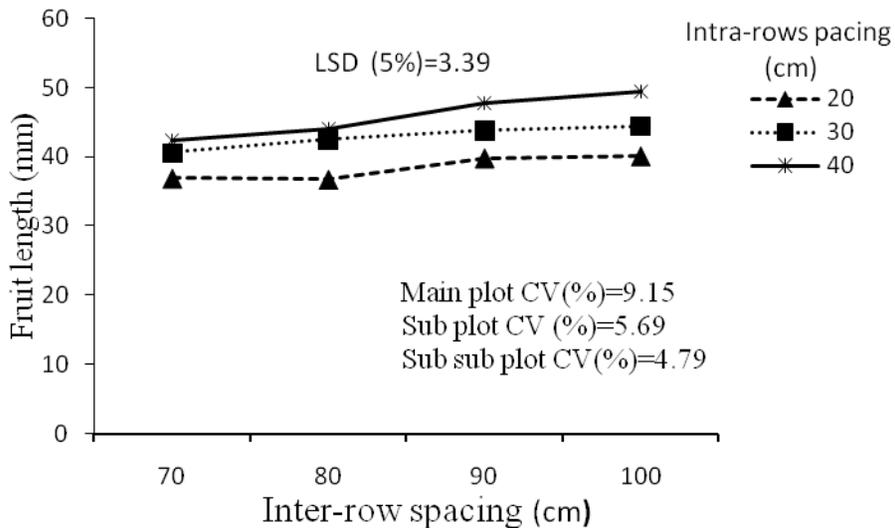


Figure 3: Fruit length of tomato cultivars as affected by the interaction effects of inter and intra-row spacing

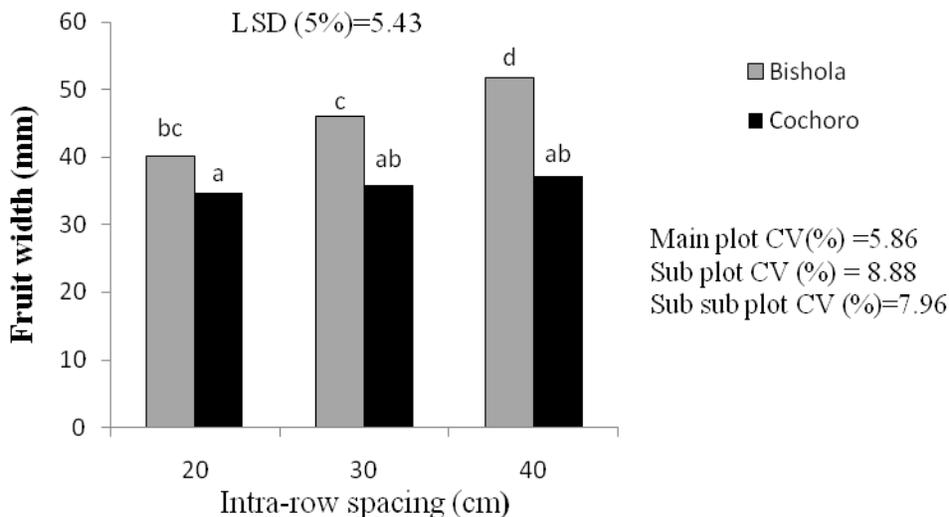


Figure 4 Fruit diameter of tomato as affected by the interaction effects of cultivar with intra-row spacing

From the result of this study can be concluded that both cultivars of tomato planted at narrow inter and intra row spacing produces higher total fruit yield than widely spaced planted tomato. However, the highest marketable fruit yield was achieved relatively at wider inter and intra row spacing. Moreover, better fruit qualities such as total soluble solid, fruit length and diameter were observed at wider (90 cm) inter-row spacing and 30/40 cm intra-row spacing of both processing (Cochoro) and fresh market (Bishola) tomato cultivars. It was therefore, concluded that growers in the study area can use 90 cm inter-row spacing and 30 cm or 40 cm intra-row spacing to produce highest marketable fruit yield and yield component for processing (Cochoro) and fresh market (Bishola) tomato cultivars under furrow irrigated condition. To obtain high marketable yield further study should be necessary to undertake more researches on genetic improvement of the cultivars and through advanced management practices such as plant spacing vs staking, drip irrigation, planting technique, diseases and insect pest management and other management options that can minimize unmarketable yield of tomato to insure better fruit yield and quality.

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