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Effects of Intra Row Spacing's on Yield and Yield Components of Tomato (Lycopersicon Esculentum, M.) Cultivars at Bako, Western Oromia, Ethiopia

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Abstract

A field experiment was carried out to determine the influence of intra-row plant spacing on growth, yield and yield components and fruit quality of tomato cultivars during 2018/2019 cropping season at Bako Agricultural TVET College, Ethiopia. Factorial combination of one inter-row spacing (70 cm), five intra-rows spacing (20,25,30,35 and 40 cm) and one cultivar (Coshoro) were laid down in RCBD design in three replications. Increasing intra-row spacing significantly increased plant height, number of branch per plant, flower number per plant, total fruit number per plant, average fruit yield per plan, days to 50% of flowering and fruit setting, days to maturity, but decreased total fruit yield. The highest plant height (80 cm) was recorded at intra-row spacing of 40 cm, whereas the lowest (68 cm) at intra-row spacing of 20 cm. The maximum number of branch per plant was recorded from wider spacing (40 cm) which is 21 whereas the minimum number of branch per plant were recorded from closer spacing (20 cm) which is 6. The highest flower number and fruit number per plant was recorded from wider spacing (40 cm) which are 70 and 48 respectively whereas the lowest flower number and fruit number per plant was recorded from closer spacing (20 cm) which are 29 and 23 respectively. Regarding to days 50% flowering and fruit setting, the highest record were obtained from wider spacing (40 cm) which are 50 and 60 days respectively, but the lowest record were obtained from closer spacing that is 36 and 58 days respectively. The maximum days to maturity were recorded from wider spacing (40 cm) which is 123 days whereas the minimum days to maturity was recorded from closer spacing (20 cm) that is 114 days. The average fruit yield were also affected by the interaction effect of intra-row spacing i.e. the highest and the lowest average fruit yield were recorded from 40 cm (2.7 kg) and 20 cm (1.5 kg) respectively. However, the highest total yield was recorded at 70 cm inter and 20 cm intra row spacing of 107 ton/ha and 85 ton/ha, correspondingly.

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Introduction

Tomato [1]. is the world's second most important vegetable after potato in terms of volume of production (Heuvelink, 2005; Pandey et al 2012). It is one of the most highly praised vegetables widely consumed in fresh and processed form. It is an excellent Source of vitamins A, C and is also widely recognized for its anti-oxidant properties treating different diseases (several cancers as well as heart disease). The fruit is also a good source of minerals such as, calcium, magnesium, potassium, sodium, and other minerals. Ripe tomato fruit is consumed fresh and utilized in the manufacture of a range of processed products such as puree, paste, powder, ketch-up, sauce, soup and canned whole fruit and the unripe green fruits are used for pickles and preserves (Heuvelink, 2005; USDA, 2010), [2]. Moreover, tomato extracts have been used in traditional medicine to treat ulcers, wounds, hemorrhoids, bums and edema during pregnancy (Heuvelink, 2005), [2].

In Ethiopia, tomato is an important cash crop to small holder farmers and is widely cultivated both under irrigation and rain fed throughout the year [3]. The crop has a significant role in human nutrition. According to Fekadu et al. (2004), the general dietary mdeficiencies of vitamins in Ethiopian population could be alleviated by a liberal consumption of tomato. Further, the authors emphasized the importance of tomato fruit in its appetizing and removal of constipation effects in addition to its pleasing and refreshing taste. Tomato production in Ethiopia is an important farming enterprise among smallholders and large-scale farmers mainly in the Awash Valley and around Lake Zeway region where the bulk of the crop is produced [3]. Fekadu et al., 2004). Furthermore, Tilaye (2010) reported that due to expansion of irrigated agriculture in the country, horticultural crops including tomato have been rapidly expanding to different new growing areas of the country. Despite this, the overall yield and quality of the crop in Ethiopia is often very low compared to both the regional and global yield levels. According to CSA (2012) the average yield of tomato in Ethiopia is 11.25 ton/ha, which is far lower than the average yield of other tomato producing countries such as USA, Spain, Italy, China, Turkey, Egypt, which produce average yield of 81.04, 73.97, 50.70, 48.7 and 33.07 ton/ha, respectively [4]. (FAO, 2010).

[3] reported that weak varietal performance and management practices that include crop establishment method, plant spacing and population, nutrient requirement in different soils, and post-harvest handling and storage facilities are the major constraints of tomato production and utilization in Ethiopia. However, considering the economic importance of tomato emphasis has been given by the national vegetable crops research project in the country to improve yield and quality of tomatoes to satisfy the growing demands from both local and export markets [3]. In the last two decades, a number of improved cultivars and other agronomic packages have been recommended to the growers to overcome this low productivity and to improve quality of tomato in Ethiopia (MoARD, 2011).

Plant spacing is among the most important factors influencing production and productivity of tomato and optimum plant spacing may help in proper utilization of land, and obtaining high yield and good quality fruits [5], (Frost and Kretchman, 1988). Plant density affects plant architecture, alters growth and developmental patterns and influences carbohydrate production and partition (Tan and Dhanvantari 1985; Frost and Kretchman 1988). Good plant arrangement can give the right plant density, which is the number of plants allowed to grow on a given unit of land for optimum yield (Heuvelink *et al*., 2009).

The spacing requirement of tomato cultivars also depends on the method and purpose of production, soil fertility, plant structure, farm practices and the type of cultivars [3], (Warner, 2003; Ara *et al*., 2007). Information on optimum plant spacing with different type of improved tomato cultivars is essential to support the growing tomato production practices for better fruit yield and market competitiveness. A recent study by Geremew *et al*. (2010), who analyzed inter-row spacing trial at Adami Tulu for processing tomato recommended 40 cm inter row and 30 cm intra row spacing for higher marketable yield even though there was no significant difference among treatments. However, the study did not consider plant spacing practices of growers and used only processing type cultivar, which have different growth and fruit characters with that of fresh market type from which the farmers are familiar with spacing practices.

There is no information regarding how diverse inter and intra-row plant spacing practiced among growers affects production and productivity of improved tomato cultivars in the Bako Tibe district. The use of proper spacing of has a dual advantage. It avoids sever competition between plants for growth factor such as water, nutrient, and light. Conversely, optimum plant population enables efficient use of available crop land without wastage (Hamid *et al.*, 2010). Therefore, conducting systematic investigation in this line is very important to come up with relevant recommendation that will help growers to increase the yield of tomato cultivars for different purposes. Accordingly practicing correct plant spacing for some of the released processing and fresh market type tomatoes are important to support the growing tomato industry.

Therefore, the objective of this study was to determine the effect of intra-row spacing on growth and development of tomato cultivars under open field production conditions with the following specific objectives:

- To identify optimum plant spacing for growth and development of tomato.
- To determine the effect of intra row spacing on growth and development of tomato.

Material and Method

Description of the study area

The study was conducted in Bako Tibe district of West Shewa Zone of Oromia Regional State which is located between 8°56'N-9°06 latitude and 37°01'E-37°12'E longitude which is located about 250 km away from the country's capital, Addis Ababa. The district has rugged topography and occasionally flat plains. The average elevation of the area is 1650 m.a.s.l. [6]. It gets a bimodal pattern of rainfall with the main rainy season extending from June to September and a short rainy season that extends from March to May with an average annual rainfall of 1300 mm. The maximum, minimum and the average temperatures of the district are about 28°c, 14°c, 21°c respectively.The dominant soil types of the area are nitosols with clay, acidic reaction, low Nitrogen, organic carbon and available Prosperous with p^H of 5-6. The soils are deep, well drained and mostly clayey in texture [7].

Experimental materials

Single tomato variety named coshoro was used for the experiment because of its availability and commercially produced infarmers' fields. This variety was collected from Bako Agricultural Research Institute department of horticulture.

Treatments and experimental design

The treatments used in theexperiment were intra-row spacing with combinations of 70 x 20, 70 x 25, 70 x 30cm (control) 70x35 cm and 70 x 40 cm which are assigned as $T_{1,}$ $T_{2,}$ $T_{3,}$ T_4 and T_5 respectively. The experiment was conducted to RCBD (random complete block design) with three replication. The total treatment plots of the experimental design were 15 plots. The size of each treatment plot is 2 mx1.7 m =3.4 m^2. The total area of experimental plots would be 15x3.4m^2 =51.3 m^2. The spacing between two consecutive plots would be 0.5 m, and the spacing between two consecutive replications would be 0.7 m.

Mental procedures

The land was cleared**,** ploughed (disked), leveled and large clods were brokendown the remains of roots stalks, non-decomposed cropresidues, weeds and other unwanted materials wasremoved. Then the soil was smoothed, fined and the land was laid out for nursery establishment. Seed were sown in nursery at June 09/2019G.C. Then during three leaf stages seedling was transplanted to the main field for theexperiment. Urea was applied in split form twice during the whole season, the first after two weeks from emergency of the seedling and the second 50days from transplanting. Weeding and watering were practiced manually as frequently as needed.

Methods of data collection

Data were collected on plant basis from the four middle rows by tagging five randomly selected plants excluding the remaining side of the rows as borders.

Plant growth and development parameters

Plant height (cm): Plant height of five randomly selected plants per plot was measured from the bottom of the plant up to the end of the main stem using ruler in centimeter and average mean of it were used to analyze this data.

Number of primarily branches per plant: Number of primary branch of five randomly selected plants was counted from the same plant where the plant height was measured.

Flowering and fruiting parameters

Data were collected from randomly selected and tagged five sample plants in the fourth row and in addition visual observations and count on flower and fruit development were made with support of Naktuinbouw (2010) growth and growth characteristic of tomato guide manual.

Fruit number: It was recorded by counting the number of fruits per cluster at red ripening stages of the fruits

Days to 50% flowering: - The number of days from transplanting to the time when 50% of the plants in the middle rows of a plot commenced flowering.

Days to 50% fruiting: - It was recorded by counting the number of days from transplanting until 50% of the plants in the middle rows of a plot start bear fruiting.

Days to Maturity (DM): It was recorded when approximately more than 90% of fruits from the Middle rows were harvested.

Yield and yield component

Fruit yield per plant (kg):- the mean fresh weight of fruits that was harvested from five randomly sampled plants and divided with its number of plant and expressed as weight of fruits per plant in gram.

Total yield (ton/ha):-was recorded by adding the weight of marketable and unmarketable fruit yield of two central rows and expressed in ton per hectare.

Methods of data analysis

The data collected was analyzed after the average mean values of the above growth and development parameters were calculated using Microsoft-Excel program and data were subjected to ANOVA using SAS software 2002 version. The mean separation was done by using the least significant difference (LSD) at 5% significant levels.

Results and discussion

Growth parameters

Plant height

Intra-row spacing had a highly significant effect (P <0.001) on mean plant height of tomato (**Table 1**). The highest mean plant height (80 cm) was recorded at intra-row spacing of 40 cm which was not significantly different from the 35 cm intra-row spacing; the lowest mean plant height (68 cm) was obtained at intra-row spacing of 20 cm which was not significantly different from the 25 cm intra-row spacing (**Table 1**).

Plant height of tomato increased with increase in intra row spacing. The decrease in plant height at narrower intra row spacing in this study may be due to the thinner and weaker stalks that contributed to early lodging. This might be due to high competition for space, light, nutrients and moisture compared to those in wider space [8,9]; because of lodging effect instead of vertical growth it produces more side branches, it tends to grow less vertically. However, wider intra-row spacing (lesser plant population density) resulted in more vertical growth by producing thick and strong stem not affected for early lodging.

Table 1: Effects of intra-row spacing on plant height of tomatoes in Bako, 2018/19.

Treatments	Plant height
40	68.8^{a}
35	60.8^{ab}
30	42^{ba}
25	37.8^{bb}
20	31.2^{bc}
Means	48.1^{a}
Lsd%5	3.82
Cv%	5.8
Fpr.<001	***

Means followed by the same letter (s) are not significantly different at 5% level of significances; ns = non significant at 5% level.

Number of branches per plant

Significant effect (p ≤ 0.05) of in the intra-row spacing was observed for number of branches per plant (Table 2). T4 (35 cm) and T5 (40 cm) planted at all tested spacing gave the highest branch per plant. The branch number obtained under this factor was statistically similar and varied from 18 and 20 branches per plant were the least branch number (6 and 7) Was obtained from T1 and T2 at intra row spacing of 20 cm and 25 cm respectively (**Table 2**), the maximum branch number per plant could be due to different type of spacing. Treatment (40 cm, 35 cm, 30 cm, 25 cm and, 20 cm), 30 cm intra row plant spacing could be recommended for better branch number per plant. This result in agreement with [10] who reported that increase in planting density resulted in reduction in number of branches per plant. When intra row spacing's increases, the number of branches per plant per unit area becomes less. More mineral nutrients highly moisture and space become available for the vegetative growth to the efficiency of photosynthesis than in dense plantation. It is also demonstrated decreased number of branches per plant in determinate type as a result of plant density.

Table 2: Effects of intra-row spacing on number of branches per plants of tomatoes in Bako, 2018/19.

Treatments intra-row spacing (cm)	Number of branches per plants
20	7.0^{bc}
25	9.2^{bb}
30	13.2^{ba}
35	16.8^{ab}
40	19.5^{a}
Means	13.2^{ba}
Lsd%5	1.48
Cv%	7.3
Fpr.<001	***

Means followed by the same letter (s) are not significantly different at 5% level of significances; ns = non significant at 5% level.

Flower number per plant

Flower number per plant had significant effects ($p \le 0.05$) of intra row spacing were observed for number of flower per plant (**Table 3**). The wider spacing (35cm and 40cm) had the highest flower per plant (56.8 and 57.2) and the lower spacing (20cm) had lowest flower per plant (38.4) This result indicates that increasing plant spacing more than 30cm for determinate types had little addition of flower number per plant. This result concur with Seid*et al.,* (2013) who reported that increasing intra row spacing greater than 30cm is not needed.

Table 3: Effects of intra-row spacing on Flower number per plant of tomatoes in Bako, 2018/19.

Treatments intra-row spacing(cm)	Flower number per plant
20	38.4^{bb}
25	40.0^{ba}
30	39.5^{bc}
35	56.8^{ab}
40	57.2^{a}
Means	46.4
Lsd%5	10.83
Cv%	16.9
Fpr.<001	***

Means followed by the same letter (s) are not significantly different at 5% level of significances; ns = non significant at 5% level.

Table 4: Effects of intra-row spacing on Fruit number of tomatoes at Bako, 2018/19.

Treatments intra-row spacing (cm)	Fruit number
20	24.2^{bc}
25	27.0^{bb}
30	28.8^{ba}
35	36.5^{ab}
40	42.2^{a}
Means	31.8
Lsd%5	4.33
Cv%	9.9
Fpr.<001	***

Means followed by the same letter (s) are not significantly different at 5% level of significances; ns = non significant at 5% level.

Fruit number

Highly significant effects ($p \le 0.01$) of intra row spacing were observed for number of fruit (**Table 4**). The wider spacing (35 cm and 40 cm) had the highest fruit per plant (41 and 48) and the lower spacing (20 cm an 25 cm) had lowest fruit per plant (23 and 25). This result indicates that increasing plant spacing more than 30 cm for determinate types had little addition of fruit number per plant. So increasing intra row spacing greater than 30 cm is not needed. Similarly this result concurs with [10].

Flowering and fruiting parameters

Days to 50% flowering and fruiting

Intra-row spacing had also highly significant effect ($P<0.01$) on days to 50% flowering, at wider spacing days being recorded at 40 cm (50 days) while the lowest mean (36 days) was observed at 20 cm intra row spacing. Intra-row spacing had also highly significant effect ($P<0.01$) on days to 50% fruit set, the maximum days being recorded at 35 cm (59 days) and 40 cm (60 days) intra rows while the lowest mean (58 days) was observed at 20 cm intra-row spacing. There was a delay of about 2 days at 40 cm intra-row spacing as compared to 20 cm. This could be due to higher competition of plants for resources in the closer intra-row spacing that may have led to stress and ultimately the plants set fruit early instead of continuous vegetative prolonged growth. Similar to the present study Hamid et al. (2010) earliest days to 50% fruit set of tomato at the closer intra-row spacing. All interaction effects were non-significant ($P>0.05$) (**Table 5**).

Table 5: Effects of intra-row spacing on Days to 50% flowering and fruiting of tomatoes in Bako, 2018/19.

Treatments	Days to 50% flowering and fruiting	Days to 50% fruiting set
20	37.8^{bc}	56.5^{bc}
25	41.0^{bb}	59.2^{bb}
30	40.8^{ba}	59.5^{ba}
35	43.5^{ab}	61.5^{ab}
40	48.5^{a}	64.2^{a}
Means	42.3	60.2
Lsd%5	1.58	1.24
Cv%	2.7	1.5
Fpr.<001	***	

Means followed by the same letter (s) are not significantly different at 5% level of significances; ns = non significant at 5% level.

Days to maturity

Interaction effect of intra-row spacing on date of maturity was significant (p<0.05) (**Table 6**). Maturity date is increased with increasing intra-row spacing; but with different rate. Increasing intra-row spacing from 20 cm to 40 cm increased the number of days to maturity. The maximum date of maturity was recorded (123) at intra-row spacing of 40 cm and minimum days of maturity (114) at intra-row spacing of 20 cm. Maturity time seemed to be a function of genotypes and environment [2]; cultivars differ with respect to their maturity period. The presence of intense plant competition at the closer intra-row spacing might have led to depletion of the available nutrients and, more stressed.

This result is in agree with the work of [11], who reported that maturity date of potato varieties from 96 to 106 days. The variation was associated with growing environment and cultural practices. Similarly [12], reported that closer intra and inter row spacing had shortened days to maturity of potato. The number of days to attain maturity is the important parameter for field production of tomato in that, it facilitates the grower to develop suitable production scheme, season as well as marketing plan [3].

Table 6: Effects of intra-row spacing on days of maturity of tomatoes in Bako, 2018/19.

Treatments	days of maturity
20	115.5^{bb}
25	118.5^{ba}
30	119.8^{ab}
35	119.8^{ab}
40	122.0^{a}
Means	119.0
Lsd%5	1.68
Cv%	1.00
Fpr.<001	***

Date of maturity as affected by the interaction effects of intra row of tomato at Bako, 2018/19. The same letters (s) on figure are not significantly different at 5% level of significance.

Yield and yield related parameters

Average fruit yield per plant

Intra-row spacing had a highly significant effect (p < 0.001) on mean fruit yield per plant. The highest fruit yield per plant (2.7 kg) was achieved at intra-row spacing of 40 cm while the lowest (1.5 kg) was obtained at intra-row spacing of 20 cm (**Table 7**).

Fruit yield per plant increased as planting density decreased that might be due to less competition. Singh and Singh (2002) indicated that the full yield potential of an individual plant is fully exploited when grown at wider spacing. Similarly, [13,14], (Nasto et al (2009) and Aminifard *et al.,* (2010) also indicated that tomato fruit yield per plant generally decreased as planting density increased.

Total fruit yield

Intra-row spacing had as well a highly significant (P <0.001) effect on yield of tomato. The highest total yield (107 ton/ ha) was achieved at intra-row spacing of 20 cm, which, however, was not significantly different from the 25 cm intra-row spacing; the lowest total yield (85 ton/ha) was obtained at intra-row spacing of 40 cm. All interaction effects were non-significant (P>0.05) (**Table 8**). [15] and Heuvelink *et al.* (2009) indicated that too wide spacing decreased yield due to in efficient utilization of space, light and nutrients. Normally, as plant population increases yield also increases proportionally due to better photosynthetic process per unit area. This finding is also confirmed the findings of [1], who reported that inter-row spacing of 40 cm recorded significantly higher mean total fruit yield per unit area than higher row spacing's in tomato. Similarly, [5] reported that total yield increased at the closer intra row spacing of 10 cm whereas the lowest was obtained at the wider intra row spacing of 40 cm.

Table 7: Effects of intra-row spacing on Average fruit yield per plant in kg of tomatoes in Bako, 2018/19.

Treatments	Average fruit yield per plant in kg
20	1.4bc
25	1.7bb
30	1.9ba
35	2.3ab
40	2.5a
Means	1.9
Lsd%5	0.16
Cv%	6.1
Fpr.<001	***

Means followed by the same letter (s) are not significantly different at 5% level of significance; Ns = non significant at 5% level.

Table 8: Effects of intra-row spacing on average fruit yield per plant in kg of tomatoes at Bako, 2018/19.

Treatments	Total fruit yield in ton /ha
20	38.4^{bc}
25	40.0^{bb}
30	39.5^{ba}
35	56.8^{ab}
40	57.2^{a}
Means	46.83
Lsd%5	10.83
Cv%	16.9
Fpr.<001	***

Means followed by the same letter (s) are not significantly different at 5% level of significance; Ns = non significant at 5% level.

Summary and conclusions

Tomato is the most important vegetable crops in Ethiopia, providing a higher income to small-scale farmers compared to other vegetable crops. However, tomato production in Ethiopia is highly constrained by several factors. Farmers get lower yields mainly due to disease, pests and inappropriate agronomic practice and lack of improved variety. Improper plant spacing is among the notable reason of low productivity of this crop.

The study was conducted to investigate the effect of different levels of intra row spacing on growth and development of the tomato under Bako condition. It was carried out under open field of Bako Agricultural TVET College practical farm site in 2018. The experiment is a one factor and five treatments (20 cm, 25 cm, 30 cm, 35 cm and 40 cm) by 70 cm intra-row spacing on Coshoro variety arranged in RCBD with four replication.

Data on plant growth and development parameter including plant height, branch number, flower number and fruit number per plant, were recorded before harvest. From the study conducted intra-raw spacing had valid effect on growth and development of tomato. Plants at 30 cm and 35 cm cm x 70 cm had higher branch number, flower and fruit number while the plant at 40 cm, 35 cm x 70 cm had higher plant height than 20 cm and 25 cm x 70 cm.

The study indicated that intra-row spacing highly significantly affected plant height, number of branch per plant, flower number per plant, total fruit number per plant and average fruit yield per plant. Wider spacing performed better in all parameters, but reduced total fruit yield. Intra-row spacing had also highly significant effect on mean days to 50% fruit set, the maximum days required at 40 cm (60 days) and 35 cm (59 days) intra-rows, while minimum (58 days) days at 20 cm.

All the parameters positively affected when intra-row spacing became wider. The maximum date of maturity was recorded 123 days from wider spacing (40 cm) and the minimum date of maturity were recorded from closer spacing (20 cm) which is 114 days. The highest total yield (107 ton/ ha) was recorded at closest intra-row spacing of 20 cm and the lowest total yield were recorded from wider spacing(40 cm) which is 85 tone/ hectare.

In general this Experiments indicates that high plant density (narrow spacing) greatly affected plant growth and development and since it affect the growth and development of the plant, it also affect final yield of tomato plant. Most resource poor farmers use cultural practice in their tomato production system. Thus to produce higher fruit yield tomato growers in the study area should be encouraged to use intra raw spacing 30 cm cm x 70 cm with the Coshoro variety.

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