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Effects of Intra-Row Spacing and N Fertilizer Rates on Yield and Yield Components of Tomato (*Lycopersicon Esculentum* L.) at Harawe, Eastern Ethiopia

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Abstract: Improper plant spacing and nitrogen fertilizer are among the main factors which constrained productivity of the tomato. Due to this gap the experiment was proposed and conducted in Sofi district, Harari People Regional State, Ethiopia in 2016 and 2017 cropping season to investigate the effect of intra-row spacing and nitrogen fertilizer on yield and yield components of tomato. Experimental treatments were nitrogen rates (0, 39, 69 and 99 kg ha^{-1}) and intra-row spacing (25, 30, 35 and 40cm). A total of 16 treatments were arranged in randomized complete block design with three replication. Melkashola Variety was used for the experiment. The results revealed that there were significant ($P<0.05$) differences for plant height, number of branches, fruit clusters per plant, number of fruits per plant due to nitrogen application. Increasing nitrogen rate from nil to 69 kg ha^{-1} increased all these parameters. Average fruit weight and fruit yield were significantly ($P<0.05$) affected due to the interaction effect of nitrogen and intra-row spacing. The highest fruit weight was recorded at 39 kg N ha^{-1} and 40cm intra-row spacing while the lowest were at 0 N and 40cm intra-row spacing. The highest fruit yield was recorded at 69 kg ha^{-1} N and 30cm intra-row spacing while the lowest was at 0 N and 40cm intra-row spacing. In conclusion, the application of 69 kg N $ha^{-1}$and 30cm intra-row spacing recorded highest fruit yield with highest economic returns (270,330 birr ha^{-1}). Based on fruit yield and economic return, combination of 69 kg N ha^{-1} and 30cm intra-row spacing was recommended for the study area and similar agro-ecology.

Keywords: Intra-row, Melkashola, Nitrogen, Spacing, Tomato

1. Introduction

Tomato (*Lycopersicon esculentum* L.) is one of the most important fruity vegetables, which due to high nutrient value, is in the second rank in regards level under cultivation and consumption [3]. It is also among the most important vegetable crops in Ethiopia. The total production of this crop in the country has shown a marked increase [8] 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 in Ethiopia is often low (125 q/ha) compared even to the neighboring African countries like Kenya (164 q/ha) [5]. In Ethiopia, farmers get lower yield mainly due to diseases and pests as well as due to sub-optimal fertilization. Mehla *et al.* [9] and Pandey et al. [13] reported that fruit yield in tomato is highly influenced by the N and P fertilizers rates applied. Similarly, Sherma et al. [14] also reported average fruit weight of tomato to have been influenced by the amount of N and P fertilizers rates applied.

Improper plant spacing is also among the notable reasons of low productivity of this crop. Lemma *et al.* [8] reported that plant spacing greatly influenced fruit yield in both fresh market and processing tomatoes. Likewise, Godfrey-Sam-Aggrey *et al.* [7] and Mehla *et al.* [9] also reported yield parameters in tomato to have been affected by spacing. Two management practices which greatly influence tomato fruit yield are spacing and fertilizer application [1]. Wider spacing on the other hand led to increase in fruit yield pe·r plant with bigger fruits and more cracked fruits per plant. Since spacing requirement of tomato depends on soil type and its inherent fertility [8] and the type of cultivars [9], the use of blanket recommendation would be inappropriate and it would be indispensable to identify appropriate recommendation for specific soil types and cultivars grown in the region. Farmers in the study area grow tomato traditionally even without the row planting and they are not using appropriate fertilizer rate. As a result of this, adequate levels of nutrients are very vital to increase the production and yield of tomato. In view of inconsistent and inadequate results concerning the combination of these two management production practices, field trial was conducted with the objectives to determine the optimum intra-row spacing and N fertilizer rate for tomato under eastern Hararghe zone.

2. Materials and Methods

2.1. Experimental Site

The Experiment was conducted in Harar People Regional State, Sofi district in Harawe on farmers land. The district was geographically lies at an altitude of 1300-1800 meters above sea level. The mean annual rainfall of the district was 400mm and maximum and minimum rain fall is 500mm and 300mm, respectively. Like some part of Ethiopia, Sofi district was characterized by the bimodal rainfall pattern. The first season was characterized by the short rainy season (*Belg*), which extends from March to May, while the second season which is the most important main rainy season (*Meher*) extends from July to October. The dry-spell period was extends from June to July and based on its duration, it may affect crop growth. The minimum and maximum temperature of the area was 25°C and 35°C, respectively with the annual average of 30°C (Harari BoA, 2016, unpublished).

2.2. Experimental Treatments and Design

For this experiment, tomato variety "Melkashola" was used as a test crop which was potentially produced by the farmers' in the area. The experimental treatments consisted of four intra-row spacing (25, 30, 35 and 40cm) and four fertilizer rates (0, 39, 69 and 99 kg N/ha). A total of 16 treatments were laid out in Randomized Complete Block Design (RCBD) in factorial arrangement with three replications. Each treatment combination was assigned randomly to experimental units within a block. The row spacing of 70cm was used for all treatments. Spacing between blocks and each plot were 1m, respectively. Based on the intra-row spacing specified, the plant populations were 57143, 47619, 40816 and 35714 plants per hectare, respectively.

2.3. Experimental Procedures

The experimental field was cultivated to a depth of 25cm by a tractor. The experimental plots were harrowed to a fine tilth manually before planting. The land was leveled well and seeds of tomato were sown in rows of 10cm on well prepared seed bed of 1 x 10m and the beds were covered with light soil and mulching grasses until emergence. The beds were supplied with supplementary irrigation during the shortage of rainfall. Finally, hardened, healthy and uniform seedlings of pencil size were transplanted at 3 to 5 leaves developed. All cultural practices were conducted as per recommendation of the area and each and every data planned to be collected were taken on time by using data record sheet. The nitrogen fertilizer (N) was applied in the form of urea whereas phosphorus (P) in the form of Triple Super phosphate (TSP) during sowing of the seed on nursery. Nitrogen was applied at two equal splits (3 weeks after transplanting and the rest half 6 weeks after transplanting) as basal application according to the rate specified in the treatments. Hand weeding and hoeing were carried out three times sequentially at seedling establishment, flowering and fruit setting. Mancozeb was applied before flowering to protect blight. All treatments were randomly assigned to the experimental plots.

2.4. Data Analysis and Management

2.4.1. Data Collected

Data collected were plant height (cm), number of branch per plant, number of cluster per plant, number of fruit per cluster, number of fruits per plant, yield per hectare, average fruit weight. Plant height was measured using ruler from the base of the plant to the tip of the shoots from ten plants of the central rows. The average numbers of branches were counted from 10 plants. The numbers of fruit clusters were counted from 10 plants of the central rows. The average numbers of fruits per cluster were also counted from 10 plants. All fruits harvested were counted to estimate the number of fruits per plant. The average fruit weight was weighted from ten fruits which harvested from central rows of the plots. The average fruit weight was expressed in gram. During harvesting, all harvest cycle fruits were weighted by using digital balance and expressed in tons per hectare.

2.4.2. Statistical Data Analysis

Data were subjected to analysis of variance using Gen-STAT Statistical Software package. Means that differed significantly were separated using the LSD (Least Significant Difference) test at 5% level of significance.

3. Results and Discussion

3.1. Soil Chemical and Physical Properties

The analysis result of the collected soil sample from the experimental site (Table 1) indicated that the soil was sandy clay loam in texture and moderately basic in reaction (pH = 8). According to range [2], the soil was medium in total nitrogen (0.171%). Similarly, the experimental site had low available phosphorus (2.893 mg kg^{-1} soil) [12]. According to range of organic matter content of soil [4], the experimental soil had moderate organic matter (2.277) contents. This moderate content of organic matter indicated that moderate soil structural condition, moderate structural stability. The soil of the experimental site had low cation exchange capacity (7.13 cmol kg^{-1} soil) and high in exchangeable potassium (9.026 cmol (+) kg^{-1} soil) (Table 1) [10].

Table 1. *Soil chemical properties of the experimental site.*

Sample	pH	CEC	OC	Mg^{2+}	Ca^{2+}	Exch.Na	Exch. K	Avail. P	TN	Texture
Soil	8	7.13	1.324	9.36	8.963	0.399	9.026	2.893	0.171	Clay loam

pH (soil to water ratio 1:2.5), CEC (cation exchangeable capacity: meq 100 g^{-1} soil), OC (Organic carbon:%), Mg^{2+} (Magnesium: cmol (+) kg^{-1} soil), Ca^{2+} (Calcium: cmol (+) kg^{-1} soil), Exch. Na (Exchangeable Sodium: cmol (+) kg^{-1} soil), Exch. K (Exchangeable Potassium: cmol (+) kg^{-1} soil), Avail. P (Available phosphorous: mg kg^{-1} soil), TN (Total Nitrogen: %).

3.2. Plant Height and Number of Branches

Plant height was significantly ($P<0.05$) affected by the application of nitrogen and intra-row spacing. Number of branches were significantly ($P<0.05$) affected due to nitrogen application, while there was no due to intra-row spacing. Application of nitrogen at 99 kg ha^{-1} increased plant height by 13.6% over no application of nitrogen. The maximum value of plant height was recorded at intra-row spacing of 40cm. Plant height increased with decreased spacing in tomato. Intra-row spacing of 35 and 40cm were statistically not different on plant height. Increasing nitrogen application from 0 to 99 kg ha^{-1} linearly increased tomato branches. The highest branches were recorded at nitrogen rate of 99 kg ha^{-1}, however, application of nitrogen at 39, 69 and 99 kg ha^{-1} statistically parity. Application of Nitrogen at 99 kg ha^{-1} increased tomato branches by about 28.9 % over no nitrogen (0 nitrogen) application. The result of current study was in line with who reported that as urea rate increased [11], plant height also increased. Increasing urea rate increased plant height and number of branches per plant. Similar to this study that the number of branches and leaves increased with increased rate of urea [11]. Plots amended with urea fertilizer were significantly better than the control in terms of plant height and number of branches.

3.3. Fruit Yield and Yield Components

3.3.1. Fruit Clusters and Fruits per Plant

Fruit clusters and fruits per plant were significantly ($P<0.05$) affected by application of nitrogen while intra-row spacing did no significant difference on both parameters. The highest fruit clusters were recorded at 69 kg ha^{-1} nitrogen application, however, application of nitrogen at 39, 69 and 99 kg ha^{-1} were statistically not different. Application of nitrogen at 69 kg ha^{-1} increased fruit clusters by about 22.8% over the control treatment (0 nitrogen). The lowest numbers of fruits per plant were recorded in control treatment. Application of nitrogen at 39, 69 and 99 kg ha^{-1} did no significant difference on number of fruits per plant. The lowest fruit clusters and fruits per plant were recorded for control treatment. According to the study, the highest increase was observed in plots treated with 108.6 kg urea, while the control plots recorded the least value of fruit length, fruit weight, and number of fruits per plant and fruit yield per hectare [11].

3.3.2. Average Fruit Weight and Fruit Yield

Average fruit weight and fruit yield were significantly ($P<0.05$) affected due to the interaction effect of nitrogen application and intra-row spacing. The highest fruit weight was recorded at 39 kg N ha^{-1} and 40cm intra-row spacing while the lowest were at 0 N and 40cm intra-row spacing. The highest fruit yield was recorded at 69 kg N ha^{-1} and 30cm intra-row spacing while the lowest was at 0 N and 40cm intra-row spacing. According to Tesfaye Balemi [16], a plant spacing of 80cm x 30cm resulted in the highest mean total fruit yield (78.6 kg $plot^{-1}$) whereas spacing of 100cm x 30cm gave the lowest mean total fruit yield (67.6 kg $plot^{-1}$). Teerapolvichitra [15] also reported the highest marketable fruit yield at closer spacing than at wider spacing, which supports the present finding. However, Godfrey-Sam-Aggrey *et al.* [7] and Mehla *et al.* [9] reported increased marketable fruit yield at wider spacing which contradicts with the present finding. In contrast to the present study, [8] reported that nitrogen had no significant effect on marketable fruits in both seasons while spacing significantly affected the number of marketable fruits in both seasons. Warner *et al.* [17] stated that fertilizer N above 100 kg N $ha^{–1}$ increased yields of green fruit, but little increase in marketable yield was obtained with N rates above 150 kg $ha^{–1}$. In this study, tomato fruit yield was significantly affected due to the interaction effect of nitrogen and intra-row spacing which recorded the highest fruit yield at 69 kg ha^{-1} and 30cm intra row spacing.

Table 2. *Effect of N rate and intra-row spacing on growth, yield and yield component of tomato over the two years (2016 & 2017).*

Nitrogen (kg/ha)	Plant height (cm)	Branches per plant	Clusters per plant	Fruits per cluster	Number of Fruits per plant
0	57.47c	3.96b	6.91b	3.071	18.79b
39	60.07bc	4.55ab	7.72ab	3.227	27.15a
69	64.34ab	4.63ab	8.95a	3.175	28.83a
99	66.51a	5.57a	8.04ab	3.306	28.16a
LSD(0.05)	4.417	1.298	1.707	NS	7.460
Intra spacing (cm)					
25	61.42ab	4.752	7.948	3.281	29.98
30	59.01b	4.41	7.771	3.123	23.42

Nitrogen (kg/ha)	Plant height (cm)	Branches per plant	Clusters per plant	Fruits per cluster	Number of Fruits per plant
35	62.10ab	4.425	8.029	3.048	23.87
40	65.86a	5.123	7.873	3.327	25.66
LSD(0.05)	4.668	NS	NS	NS	NS
CV (%)	12.4	48.4	37.7	20.8	50.6

Table 3. *Interaction effect of nitrogen rate and intra row spacing on average fruit weight (g).*

	Intra-row spacing-(cm)			
N rate (kg/ha)	25	30	35	40
0	52.53abcde	48.52cde	48.10cde	42.73e
39	49.28cde	55.28abcd	56.92abc	62.32a
69	47.06cde	44.18de	52.89abcde	59.12abc
99	50.20bcde	49.08cde	48.04cde	61.45ab
	LSD (0.05) =10.349,		CV (%) = 17.4	

Table 4. *Interaction effect of nitrogen and intra-row spacing on fruit yield (tons/ha)-over the two years (2016 and 2017).*

	Intra-row spacing (cm)			
Nitrogen	25	30	35	40
0	25.0ab	21.9ab	21.ab	18.8b
39	33.2ab	33.5ab	27.3ab	23.9ab
69	29.7ab	38.1a	28.2ab	26.8ab
99	31.5ab	23.5ab	29.2ab	23.0ab
	LSD(0.05) = 14.28		CV(%) 45.8	

3.4. Partial Budget Analysis

Application of nitrogen rate at 69 kg ha^{-1} and intra-row spacing of 30 cm recorded maximum net return followed by combination of nitrogen and intra-row spacing at 39 kg ha^{-1} and 30 cm, and 39 kg ha^{-1} and 25 cm, respectively, from tomato production. The lowest net returns were obtained at 0 N in all treatment combinations.

Table 5. *Partial budget analysis of Nitrogen fertilizer and intra-row spacing of tomato.*

(Spacing + N)	UFY (kg ha^{-1})	AFY (kg ha^{-1})	GR (birr ha^{-1})	TVC (birr ha^{-1})	NR (birr ha^{-1})	MRR(%)
40 -- 0	18747	16872	134976	2170	132806	
35 -- 0	20990	18891	151128	2480	148648	5110
40 -- 39	23931	21538	172304	2622	169682	14813
30 -- 0	21857	19671	157368	2894	154474	D
35 -- 39	27250	24525	196200	2932	193268	102089
40 -- 69	26758	24083	192664	2970	189694	D
35 -- 69	28160	25344	202752	3280	199472	3154
40 -- 99	22990	20691	165528	3318	162210	D
30 -- 39	33458	30113	240904	3346	237558	269100
25 -- 0	25025	22523	180184	3472	176712	D
35 -- 99	29227	26304	210432	3628	206804	19290
30 -- 69	38058	34253	274024	3694	270330	96252
25 -- 39	33203	29883	239064	3924	235140	D
30 -- 99	23458	21112	168896	4032	164864	D
25 -- 69	29678	26711	213688	4272	209416	18563
25 -- 99	31538	28385	227080	4620	222460	3748

N =Nitrogen, UFY=Unadjusted Fruit Yield, AFY=Adjusted Fruit Yield, GR=Gross Return, TVC=Total Variable Cost, NR=Net Return, MRR=Marginal Rate of Return, D=Dominated treatments

4. Conclusion

The experiment was conducted for two consecutive cropping season to determine the effect of intra-row spacing and nitrogen fertilizer rate on tomato yield and yield parameters. The results indicated that there were significant effects among treatments for plant height, branches per plant, clusters per plant and number of fruits per plant due to the application of nitrogen. There was an interaction effect of nitrogen application and intra-row spacing on average fruit weight and fruit yield. The highest fruit weight was obtained by the application of 39 kg ha^{-1} N at intra-row spacing of 40cm while fruit yield was at 69 kg ha^{-1} N and 30cm intra-row spacing. In conclusion, application of 69 kg N ha^{-1}and intra-row spacing at 30cm, recorded highest fruit yield with highest economic returns (270,330 birr ha^{-1}). Based on fruit yield and economic return, combination of 69 kg N ha^{-1} and 30cm intra-row spacing was recommended for the study area and similar agro-ecology.

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