

Influence of Stage and Intensity of Truss Pruning on Fruit Yield and Quality of Tomato (*Solanum lycopersicum* L.) at Melkassa

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Abstract: The influence of stage and intensity of truss pruning on yield and quality of tomato (*Solanum lycopersicum* L.) was investigated in the open field at Melkassa Agricultural Research Center. Three stages of pruning (bud, anthesis, fruit set) and four levels of pruning (control, one-truss, two-truss and three-truss) were arranged in Randomized Complete Block Design (RCBD) with three replications. The result showed increasing pruning intensity increased the total leaf area; fruit set percentage, average fruit fresh weight, pericarp thickness, fruit diameter, pH and total soluble solids content. However, number of fruit per plant, marketable fruit yield and total fruit yield decreased with increasing intensity of pruning. In general the present study showed that pruning did not significantly improve tomato fruit yield. Nevertheless, truss pruning found to be effective in improving tomato fruit quality such as average fruit weight, fruit size (fruit diameter), pericarp thickness and total soluble solids. It is also essential that further study should be conducted on other improved tomato varieties in different location to determine the effect of pruning and to give concrete recommendation at what intensity pruning should be effective to improve fruit yield and quality.

Key words: Tomato • Yield • Quality • Pruning • Stage and Intensity

INTRODUCTION

Vegetable production is one of the agricultural activities and among the fastest growing in the world and has great potential for alleviating poverty, especially among the rural poor [1]. Moreover, due to their short production cycles and relatively high per unit area compared to most cereals, vegetable production is more profitable, increases employment and income-generating opportunities and brings about increasing commercialization of the rural sector. Tomato is one of the major food crops, representing the second highest produced and consumed vegetable in worldwide [2]. The crop is produced in both small scale and large scale farmers for local consumption and export.

The crop is highly nutritious and main food sources of carotenoids, providing an estimated 80% of daily intake of lycopene and of folate, ascorbic acid, flavonoids,

a-tocopherol and potassium [3, 4]. Tomato also act as antioxidant because its phytochemicals, in particular lycopene, a very efficient radical scavenger capable to fight reactive oxygen species known to cause cancer, cataracts, heart disease, hypertension, stroke and diabetes [5, 6]. In addition, extracts from tomato fruit are used in traditional medicine to treat ulcers, wounds, hemorrhoids, burns and edema during pregnancy [7].

Furthermore, it serves also as a good source of income for those involved in production and marketing. Despite the increasing importance of tomato in Ethiopia, the total production and productivity is far below than the average yield of major producers in the world. According to FAOSTAT [8], the average yield of tomato in Ethiopia is ranging from 6.5-24.0 ton ha⁻¹ compared with average yields of 51, 41, 36 and 34 ton ha⁻¹ in America, Europe, Asia and the entire world, respectively. It has been also reported the current productivity of this crop under

farmers' field is 9 ton ha⁻¹ [9]. This is mainly due to inadequate agronomic management, shortage of improved varieties, diseases, insect pests, high post-harvest loss [10] and adverse environmental factors [11, 12].

Thus, improved agronomic management such as pruning and staking could improve the yield and quality of tomatoes. This leads to improving smallholders' tomato production which contributes in enhancing food security and to alleviating poverty. Pruning in tomatoes has been reported to increase yields and quality [13]. Pruning is the removal of suckers (axillary shoots), flower and fruits. The degree to which pruning is needed will vary with the variety used and the practice can significantly impact yield and quality. It is believed that pruning of some flowers and fruit in tomato results in assimilate re-distribution to the remaining fruit, increasing their size [14]. On the other hands, plants that produce vigorous foliage that are not pruned will produce more, but smaller fruit [15]. The extent of re-distribution of assimilates to the remaining fruit appears to depend also mainly on the sink-strength of fruit (which varies with the age of fruit) and on the stage of pruning [16].

In general, maintaining fruit size with in a preferred size range by altering fruit number is achieved by fruit thinning thus increasing the supply of assimilates to the remaining fruit [17]. Furthermore, low sink demand brought about by fruit or flower pruning is said to have a negative feedback control on photosynthesis. To avoid yield losses the degree of thinning must be adjusted to obtain a desirable fruit size and yield in the remaining fruit [17]. However, other researchers have reported conflicting results that pruning either reduces tomato yields and/or quality or has no effect at all on tomato production [18]. It is therefore, not clear whether tomato pruning is worthwhile or not. In Ethiopia, flower and fruit pruning in tomato are not very common practice as farmers do not know the benefits and little research has been done to investigate the effect of tomato pruning. The present study, therefore, has been designed to investigate the influences of truss pruning at different stage and intensity on yield, yield components and quality of tomato.

MATERIALS AND METHODS

Study Site: The study was carried out at vegetable nursery in Melkassa Agricultural Research Center from July to November 2015. The site is 117 km away from Addis Ababa and 17 km away from Adama town. The experimental site is situated at latitude of 12° 07' N, longitude of 37° 52' E and an altitude of 1800 meter above

sea level. The area receives average annual rain fall of 890 mm with mean maximum and minimum temperatures of 28.5°C and 13.8°C, respectively and it has a gentle slope of 1-3% and the texture of the soil is sandy loam [19].

Study Material and Experimental Design: Melkashola variety was used since it is a popular variety grown in the study area. The experiment was arranged in a Randomized Complete Block Design (RCBD) with three replications. The experiment consisted of four levels of pruning (first truss the first two trusses, the first three trusses and without pruning (control)) and three stages of pruning (at bud stage when the flower bud is visible, at anthesis when the first flower in a particular truss opens and at fruit set when the first fruit is 2 mm in diameter). The experimental plot had a gross area of 13.5 m² with 2.7 m length and 5 m width and a net harvest area of 4.86 m² (2.7m × 1.8m). The distance between plots and blocks were 1 m and 1.5 m, respectively. Plants were spaced at 100 cm between rows and 30 cm within row. Each plot had five rows with a plant population of 45 per plot which is equivalent to 33333 plants per hectare.

Data Collected

Total Leaf Area (cm²): Five plants were randomly selected from the center of the two rows. The mean of the total leaf area of a plant in a plot was obtained by adding the total leaf area of the selected plants and then dividing the sum by the number of selected plants. The total leaf area of a plant was obtained by multiplying the area of each leaf by the total number of leaves in the plant. The area of each leaf was calculated using formulae developed by Blanco and Folegatti [19] as:

$$LA = 0.708 (LW)^2 - 10.44LW + 83.4$$

where:

LA= leaf area

LW= leaf width (cm)

Yield Assessment: Yield and yield components data were taken from the two central rows and five plants were also selected for the determination of yield and yield components these included:

Number of Flowers per Truss: Tomato plants were tagged from each plot for this purpose and the numbers of flowers were counted from lower, middle and upper trusses; the mean number of flowers per truss was computed.

Fruit Set Percentage: Was obtained by dividing number of fruits by the number of flowers per truss and means from lower, middle and upper part was calculated.

Number of Fruit per Truss: Number of fruits in all the trusses in each selected plant was counted and then the total number of fruits in all the trusses was divided by the number of trusses.

Number of Fruit per Plant: This is the total number of fruits of successive harvests and the average number of fruits per plant was obtained by counting the total number of fruits in each selected plant and then dividing it by the number of selected plants.

Average Fresh Weight of Fruit (g): This was obtained by dividing total fruit fresh mass per plant by the total number of fruit per plant.

Marketable Fruit Yield per Plant (kg): Fruits whose diameter were > 3 cm and which were free of damage were considered as marketable at each harvest; the average marketable fruit yield per plant was obtained by adding the marketable fruit yield obtained from the selected plants and then dividing the sum by the number of selected plants. The total marketable fruit yield per plant is the sum of successive harvests.

Unmarketable Fruit Yield per Plant (kg): Fruits whose diameter were ≤ 3 cm and which were damaged by insect, diseases, sun burn, etc. were considered as unmarketable and the average un marketable fruit yield per plant was obtained by adding unmarketable fruit yield obtained from the selected plants and then dividing the sum by the number of selected plants.

Total Fruit Yield per Hectare (Ton): This was obtained by converting the marketable fruit yield obtained from the net harvest area (486 m^2) into hectare. At each harvest, all the marketable fruits were harvested from the net harvest area and the total marketable fruit yield of successive harvests was converted into hectare.

Fruit Quality

Fruit Diameter (cm): Five fruits of different size (very large, large, medium, small and very small) were collected from each selected plant and the diameter of each fruit was measured by using caliper. The mean diameter of a

fruit was obtained by adding the diameter of all the selected fruits and then dividing the sum by the number of selected fruits.

Pericarp Thickness (mm): Five fruits of different size (very large, large, medium, small and very small) were collected from each selected plant. Each fruit was cut into two halves through the equator and the thickness of the pericarp was measured by a caliper. The mean thickness of the pericarp was obtained by adding the pericarp thickness of all the selected fruits and then dividing the sum by the number of selected fruits.

Total Soluble Solid (%): Three ripened fruits were collected from each plot and from each plant, juice was extracted and the level of the soluble solids in the juice was determined by placing a drop the juice sample on a refract meter (CE S. NO. AO 2371). The prism of the refract meter was washed with distilled water and dried before use between samples. The refract meter was standardized against distilled water. The mean total soluble solid of the fruit was obtained adding the total soluble solid of the three samples and then dividing the sum by the number of the samples.

Fruit pH: Like total soluble solid determination, three ripened fruits were collected from each plot as a sample and 25 ml of juice was extracted from each fruit and poured into a beaker and the juice was stirred by a stirring bar and then electrodes were inserted into the beaker and finally the pH of each fruit was recorded from the pH meter. The pH meter was calibrated using buffer solution before use and the electrodes were rinsed with distilled water between readings. The mean pH of the fruit was obtained by adding the pH of the three samples and then dividing the sum by the number of samples.

Data Analysis: The analysis of variance was done using 'The SAS system for windows V9.2' software and comparisons of means were made by using Least Significant Difference (LSD) at 5% probability levels.

RESULTS AND DISCUSSION

Total Leaf Area: Total leaf area of tomato significantly affected by the interaction between stage and intensity of pruning ($P < 0.05$) (Table 1). The highest leaf area obtained when three trusses were removed at fruit set stage.

Table 1: Total leaf area (cm²) of tomato as influenced by the interaction effects of stage and intensity of truss pruning

Stage	Intensity of truss pruning			
	Control	One-truss	Two-truss	Three-truss
Bud	3049j	3238i	5508f	8669b
Anthesis	2899l	3500h	6467e	8239c
Fruit set	2952k	3721g	7388d	9940a
LSD	0.0001			
CV (%)	7.51			

Different letters in the same column and across column indicate significant difference acc (P<0.05)

Table 2: The interaction effect of stage and intensity of truss pruning on number of flower per truss of tomato

Pruning	Intensity of truss pruning			
	Control	One-truss	Two-truss	Three-truss
Bud	3.00h	3.12g	3.41d	3.71b
Anthesis	2.71i	3.21f	3.61c	4.00a
Fruit set	2.61j	3.00h	3.31e	3.71b
LSD	0.0156			
CV (%)	3			

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

Table 3: Interaction effect of stage and intensity of truss pruning on fruit set percentage of tomato

Pruning	Intensity of truss pruning			
	Control	One-truss	Two-truss	Three-truss
Bud	56.41l	64.41e	65.0c	69.07a
Anthesis	61.03k	61.35j	61.6i	63.41g
Fruit set	63.0h	63.51f	64.64d	67.84b
LSD	0.0437			
CV (%)	2.93			

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

As fruits are the strong sink of the plant, a reduction in fruit load could favor the distribution of assimilates to the vegetative parts of the plant (e.g. leaves) and subsequently stimulate leaf growth. Ehret *et al.* [21] also found higher foliage: fruit ratio when some fruits were pruned from tomato plants as compared to the non-pruned ones. Tekalign [22] also reported similar findings for potato which flower and fruit removal significantly increased total leaf area.

Number of Flower per Truss: A significant interaction between stage and intensity of pruning was observed on number flower per truss (P< 0.05; Table 2). The highest number of flower per truss obtained when three trusses removed at anthesis stage while the lowest from the unpruned plants (Table 2). This is in agreement with the findings of Murneek [23] who noted that the presence of fruit on a plant could lead to a decrease in inflorescence size and abortion of the flower buds.

Fruit Set Percentage: Fruit set percentage of tomato was significantly affected by the interaction effects of stage

and intensity of truss pruning (Table 3). This indicates that there is a synergetic effect between stage and intensity of truss pruning. The highest fruit set percentage (69.07%) was obtained when three trusses were removed at bud stage while the lowest (56.41%) was from the unpruned plants. This probably due to strong competition among developing flower buds for unpruned tomato plant which leads to flower abortion and there by lower fruit set [23].

Number of Fruit per Truss: The number of fruit per truss was significantly affected by stage of pruning. The highest numbers of fruits were observed at bud stage of pruning compared to fruit set stage pruning. Furthermore, a significant variation in number of fruit per truss was observed by the intensity of pruning as presented in Table 4. The highest fruit number per truss was obtained in the control (unpruned) treatment while the lowest obtained from three trusses pruned treatment. Tsedal [24] also reported similar result for three-truss pruned treatment which gave the lowest fruit number.

Table 4: Number of fruit per truss and per plant of tomato as affected by different stages and intensity of truss pruning.

Pruning	Number of fruits	Number of fruits stage per truss per plant
Bud	7.0a	26.0a
Anthesis	6.0a	26.0a
Fruit set	6.0b	24.0b
LSD	0.053	0.047
Intensity		
Control	8.0d	30.0a
One- truss	7.0c	26.0b
Two-truss	6.5b	23.0c
Three-truss	6.0a	22.2d
LSD	0.06	0.05
CV (%)	1.02	0.22

Means of the same sub effect within a column followed by the same letter are not significantly different at the prescribed level of significance ($P < 0.05$).

Table 5: Interaction effect of stage and level of truss pruning on fresh mass (g) per plant of tomato

Pruning stage	Intensity of truss pruning			
	Control	One-truss	Two-truss	Three-truss
Bud	80.3j	86.5i	94.4d	98.4a
Anthesis	86.5i	88.1h	89.6f	91.6e
Fruit set	76.2k	88.5g	96.4b	95.2c
LSD	0.017			
CV (%)	3.56			

Means of the same main effect within a column followed by the same letter are not significantly different at the prescribed level of significance (5% and 1%).

Table 6: Marketable, unmarketable, total fruit yield per hectare of tomato as affected by stage and intensity of truss pruning

Stage	Fruit yield (ton ha ⁻¹)		
	Marketable	Unmarketable	Total fruit yield
Bud	53.67	2.00	55.67
Anthesis	51.00	2.00	53.00
Fruit set	53.00	1.20	54.20
LSD	0.0067	0.003	0.006
	ns	ns	ns
Intensity			
Control	55.99a	0.90d	56.99ab
One -truss	53.99b	1.30c	55.33b
Two truss	52.33c	1.67b	53.20c
Three-truss	48.99d	1.67a b	50.60d
LSD	0.0079	0.0034	0.0072
CV (%)	0.51	0.71	0.46

Means of the same main effect within a column followed by the same letter are not significantly different at the prescribed level of significance (5% and 1%).

Number of Fruit per Plant: The number of fruit per plant was significantly affected by the stage of pruning (Table 4). The number of fruit per plant decreased with increase in the level of pruning intensity. However, number of fruits per plant was not significantly affected by the interaction effects of stage and intensity of truss pruning (Table 4).

Average Fruit Fresh Weight: Interaction effect between stage and intensity of truss pruning on average fruit fresh weight was observed (Table 5). The highest

average fruit fresh weight (98.4g) was obtained when three trusses were removed at bud stage while the lowest (76.22g) was from the unpruned plants. This is probably due to low fruit load as the result of fruit pruning which leads to more assimilate transport to remaining fruit and consequently, gives heavier and larger size fruit [25]. The present result is also in agreement with the finding of Maboko and Du Plooy [26] who reported that higher fruit load per plant resulted in reduction in source to sink ratio and subsequently reduced fruit weight.

Marketable Fruit Yield: A significant effect of intensity of pruning was observed for marketable yield (Table 6).

The highest marketable fruit yield obtained from the unpruned treatment (55.99 ton ha⁻¹) while the three-truss pruned treatments gave the lowest (48.99 ton ha⁻¹) marketable yield. The reduction in marketable yield could be explained by reduction of number of fruit per plant as a result of increased intensity of pruning. However, average fresh fruit weight increased with increased intensity of truss pruning (Table 5). This implies that fruit number plant was responsible for increasing marketable yield more than fruit weight. Thus, severe pruning can cause yield reduction and increased physiological disorders such as sun burn, blossom end rot and cat facing which are known to reduce the marketability of tomato fruit [15].

Unmarketable Fruit Yield: Unmarketable fruit yield per hectare was not significantly affected by the stage of pruning but it was significantly affected by the intensity of pruning (Table 6). The highest unmarketable fruit yield per plant was obtained from the three- trusses pruned treatments and followed by two trusses pruned treatments. This might be because if too many fruits are pruned from the plant, those remaining may be more prone to growth disorders such as cracking [27] blossom-end rot [28], sun burn and cat facing [15] and fruit deformation [29]. The incidence of blossom end rot was higher in the three trusses pruned treatments than the other treatments in the current study.

Total Fruit Yield: Total fruit yield per hectare was not significantly affected by the stage of pruning but it was significantly affected by the intensity of pruning (Table 6). Total fruit yield per hectare decreased with increasing pruning intensity. Thus, the highest total fruit yield obtained from the control treatment followed by the one, two and three truss pruned treatments. The reduction in total fruit yield can be also explained by a decreased number of fruit per plant as a result of truss pruning. This result is in accordance with the finding of Tindall [30] who stated that removal of flowers and fruit may result in a reduction of total yield.

Fruit Quality

Fruit Diameter: Fruit diameter was significantly affected by the stage of pruning (Table 7). Tomato fruits with the biggest diameter were obtained when trusses were

removed at bud stage even though it was not significantly different from the anthesis stage. Fruit diameter was also significantly affected by the intensity of pruning and increased with increasing pruning intensity. This has been explained by the increased allocation of available assimilates to the remaining fruit due to the increase source: sink ratio created by the reduction of sink load [17, 31-33]. Baldet *et al.* [34] also reported that reduction of fruit load from five fruits to one fruit per truss after 30 days of removal resulted in an increase fruit diameter by 28%. Fruit diameter was not significantly affected by the interaction effects of stage and intensity of truss pruning.

Fruit pH: Fruit chemical quality traits were significantly affected by fruit pruning systems. Fruit pH significantly increased with increasing pruning intensity. But, fruit pH was not significantly influenced by the stage of pruning (Table 7). pH is very important because acidity influences the thermal processing conditions required for producing safe products.

Pericarp Thickness: Pericarp thickness of tomato was significantly affected by the interaction effects of stage and intensity of truss pruning (Table 8). The removal of three trusses at fruit set stage produced fruit with the thickest pericarp (5.7 mm) while the control gave the least (3.5mm). Alley and Kelly [35] observed similar results in sweet pepper in which removal of the some fruit significantly increased the pericarp thickness of the remaining fruit.

Total Soluble Solid (TSS): The TSS content of tomato was significantly affected by the interaction effects of stage and intensity of truss pruning (Table 9). Fruits with the highest TSS content were obtained when two trusses were removed at bud stage (6.26) and fruit set stage (6.22) while the lowest TSS (3.5) was observed from unpruned treatment at anthesis stage. An increase in fruit quality aspects could be due to low fruit load as a result of pruning treatment that cause more assimilates production diverted to fewer sinks [36].

Similar result was observed by Abdel-Razzak *et al.* [37] who reported that fruit pruning increased fruit quality (i.e TSS, pH). In addition to pruning management, tomato fruit yield and quality also affected by genetic trait and growing condition [11, 12 and 38] as the result of change in physiological response of to tomato these variables [38].

Table 7: Fruit diameter and pH as influenced by different stages and levels of truss pruning

Stage	Fruit diameter (cm)	pH
Bud	45.2a	4.92a
Anthesis	42.7b	4.89ab
Fruit set	41.0c	4.91a
LSD	0.2398	0.0081
Intensity		
Control	38.0d	4.41d
One –truss	40.66c	4.73c
Two truss	45.00b	5.11b
Three-truss	48.33a	5.39a
LSD	0.2768	0.0093
CV (%)	0.67	0.2

Means of the same main effect within a column followed by the same letter are not significantly different at the described level of significance (5% and 1%).

Table 8: Pericarp thickness as influenced by the interaction effect of stage and level of truss pruning of tomato

Pruning	Pericarp thickness (mm)			
	Control	One-truss	Two-truss	Three-truss
Bud	4.2h	5.0d	4.4g	5.4b
Anthesis	3.5l	4.8e	4.203i	5.2c
Fruit set	4.0j	4.6f	3.7k	5.7a
LSD	0.0066			
CV	4.87			

Means of the same main effect within a column followed by the same letter are not significantly different at the prescribed level of significance (5%).

Table 9: Total soluble solids content as influenced by the interaction effect of stage and level of truss pruning of tomato.

Stage	Intensity of truss pruning			
	Control	One-truss	Two-truss	Three-truss
Bud	4.81j	5.25g	6.26a	6.05e
Anthesis	4.77k	5.2h	6.1c	5.9f
Fruit set	4.76l	5.11i	6.22b	6.08d
LSD	0.0063			
CV (%)	0.86			

Means of the same main effect within a column followed by the same letter are not significantly different at the prescribed level of significance (P<0.05)

CONCLUSION

A significantly interaction between stage and intensity of truss pruning was observed on total leaf area, number of flower and fruit per plant, fruit set percentage, Average fresh weight, pericarp thickness, total soluble solids content. Total leaf area, fruit set percentage, individual fruit fresh weight, pericarp thickness, fruit diameter pH and total soluble solids content increased with increasing pruning intensity. However, number of fruit per plant, marketable fruit yield and total fruit yield decreased with increasing intensity of pruning. In general the present study showed that pruning did not significantly improve tomato fruit yield. Nevertheless, truss pruning found to be effective in improving tomato fruit quality such as average fruit weight, fruit size (fruit diameter), pericarp thickness

and total soluble solids. It is also essential that further study should be conducted on other improved tomato varieties in different locations to give concrete recommendation.

REFERENCES

1. Kanyomeka, L. and B. Shivute, 2005. Influence of pruning on tomato production under controlled environments. *Agricultura Tropicaet Subtropica*, 32(2): 79-81.
2. Daniela Erba, M. Cristina Casiraghi, Albert Ribas, Rafaela Cáceres and Oriol Marfà, 2013. Nutritional value of tomatoes ([i]*Solanum lycopersicum*[/i] L.) grown in greenhouse by different agronomic techniques. *Journal of Food Composition and Analysis*, 31(2): 245-251.

3. Simonne, Amy H. Bridget K. Behe and Maurice M. Marshall, 2006. Consumers prefer low-priced and highly lycopene-content fresh-market tomatoes. *Hort Technology*, 16(4): 674-6819.
4. Willcox, J.K., G.L. Catignani and S. Lazarus, 2003. Tomatoes and cardiovascular health. *Critical Review in Food Science and Nutrition*, 43: 1-18.
5. Demissie, T., A.A. Ali and D. Zerfu, 2009. Availability and consumption of fruits and vegetables in nine regions of Ethiopia with special emphasis to vitamin A deficiency. In: *Ethiopian Journal of Health Development*, 23(3): 216-222.
6. Riso, P., F. Visioli, D. Erba, G. Testolin and M. Porrini, 2004. Lycopene and vitamin C concentrations increase in plasma and lymphocytes after tomato intake. Effects on cellular antioxidant protection. *European Journal of Clinical Nutrition*, 58: 1350-1358.
7. Food and Agriculture Organization of the United Nations (FAO), 1996.
8. Food and Agriculture Organization of the United Nations (FAO), 2010. Production year book. Rome, Italy.
9. Abuqamar, S., M.F. Chai, H. Luo and T. Mengiste, 2008. Tomato protein kinase 1b mediates signaling of plant responses to necrotrophic fungi and insect herbivory. *The Plant Cell*, 20(7): 1964-1983.
10. Meseret, D., 2010. Evaluation of Tomato (*Lycopersicon esculentum*) Varieties for fruit yield, quality and shelf life. M.Sc. Thesis presented to School of Graduate Studies, Jimma University.
11. Kassaye Tolessa and E.P. Heuvelink, 2018. Pollen Viability and Fruit Set of Tomato Introgression Lines (*Solanum esculentum* X *L. Chmielewskii*) at Moderately High Temperature Regimes, *World Applied Sciences Journal*, 36(1): 29-38.
12. Yebirzaf, Y., B. Derbew and T. Kassaye, 2016. Tomato (*Solanum lycopersicum* L.) Yield and Fruit and Quality Attributes as Affected by Varieties and Growth Condition *World Journal of Agricultural Sciences*, 12(6): 404-408.
13. Hadfield, 1989. The A -Z of vegetable gardening in South Africa. Struikhof publisher. Johannesburg. JONES, J.P., (1991). *Compendium of tomato diseases*. Ed. APS press. New York.
14. Rubatzky, V.E. and M. Yamaguchi, 1996. *World vegetables: Principles, Production and Nutritive Values*. 2nd edition. International Thomson Publishing. Department of vegetable crops. University of California, USA, pp: 551.
15. Terry Kelly, W. and G. Boyhan, 2006. *Commercial Tomato Production Hand book*, USA, pp: 1-65
16. Kinet, J. and M. Peet, 1997. Tomato. In: Wien, H. (Ed), *the physiology of vegetable crops*. CAB International, Wallingford, UK, pp: 207-258.
17. Cockshull, K. and L.C. Ho, 1995. Regulation of tomato fruit size by plant density and truss thinning. *J. Hortic. Sci.*, 70: 395-407.
18. Resh, H.M., 1997. *Hydroponics tomatoes*. Ed.: Woodbridge press publishing co. California. Srinivasan, Veeraghavathathan, D., Kanthaswamy, V. And Thiruvudainambi, S., (2001). *The effect of spacing, training and pruning in hybrid tomato*. Ed.: CAB international.
19. Gebru Jember, Abebe Tadege, 2011. *Natural Resources Management and Environment. Proceedings from National Workshop on Strengthening Capacity for Climate Change Adaptation in the Agriculture Sector in Ethiopia*. Climate change, variability, trends and potential impacts and risks in major agro-ecological zones in Oromiya region, Ethiopia. Nazreth, Ethiopia. Draft document.
20. Blanco, F.F. and M.V. Folegatti, 2003. A new method for estimating the leaf area index of cucumber and tomato plants. *Horticultura Brasileira*, Brasilia, 21(4): 666-669
21. Ehret, D., T. Helmer and J. Hall, 1993. Cuticle cracking in tomato fruit. *Journal of Horticultural Science*, 68: 195-201.
22. Tekalign, T., 1997. The effect of flower and fruit removal on vegetative growth and tuber yield of potato. M.Sc. Thesis, Ethiopia.
23. Murneek, A., 1926. Effects of correlation between vegetative and Reproductive functions in the tomato (*Lycopersicon esculentum* Mill). *Plant physiology*, 1: 3-56
24. Tsedal, T., 2004. Yield and Quality response of tomato and hot pepper to pruning, Submitted in Partial Fulfillment of the requirements for the degree Magister Scientiae: Agronomy. Department of Plant Production and Soil Science. Faculty of natural and agricultural sciences. University of Pretoria, Pretoria, pp: 1-132.
25. Heuvelink, E. and R. Buiskool, 1995. Influence of sink- source interaction on dry matter production in tomato. *Annals of Botany*, 75: 381-389.

26. Maboko, M.M. and C.P. Du Plooy, 2008. Effect of pruning on yield and quality of hydroponically grown cherry tomato (*Lycopersicon esculentum*). South African Journal of Plant and Soil, 25: 178-181.
27. Morgan, L. and Simon Lennard, 2000. Hydroponic capsicum production: a comprehensive, practical and scientific guide to commercial hydroponic capsicum production. Casper Publications PtyLtd.
28. De Kreijl, C., 1992. Blossom-end rot. Compte rendu de la re' union du 25 f'evrier. Cultilene, division d'Isover, St- Gobain, France.
29. Aloni, B., E. Pressman and L. Karni, 1999. The effect of fruit load, defoliation and nighttemperature on the morphology of pepper flowers and on fruit shape. Journal of Annalsof Botany, 83: 529-534.
30. Tindall, H.D., 1983. Vegetables in the tropics. Macmillan education LTD, Houndmills, Basing stroke, Hampshire RG 21 2XS. London, pp: 357.
31. Tanaka, A., K. Fujita and K. Kikushi, 1974. Nutrio-physiological studies on the tomato plant. III. Photosynthetic rate of individual leaves in relation to the dry matter production of plant. Soil Sci. Plant Nutrition, 20: 173-183.
32. Ramirez, V., L. Martinez and P. Arguedas, 1977. Pruning systems in tomato. Journal of Tropical Alajuela, 10: 16.
33. Saglam, N., A. Yazgan, Y. Tuzel, S. Burrage, B. Bailey, A. Gul, A. Smith and O. Tunlay, 1999. Effect of fruit number per truss on yield and quality in tomato. Journal of Acta Horticulturae, 491: 261-26.
34. Baldet, P., C. Devaux, C. Chevalier, R. Brouquisse, D. Just and P. Raymond, 2002. Contrasted responses to carbohydrate limitation in tomato fruit at two stages of development. Plant, Cell and Environment, 25: 1639-1649.
35. Ali and Kelly, W., 1992. The effects of inter fruit competition on the size of sweet pepper *Capsicum annum* L.) Fruit Scientia Horticulturae, 52: 69-76
36. Hesami, A., S. Sarikhani Khorami and S. Hosseini, 2012. Effect of Shoot Pruningand Flower Thinning on Quality and Quantity of Semi-determinate Tomato (*Lycopersicon esculentum* Mill.). Not. Sci. Biol., 4: 108-111.
37. Abdel-Razzak, Wahb-Allah, Ibrahim, Alenazi and A. Alsadon, 2016. Response of Cherry Tomato to Irrigation Levels and Fruit Pruning under Greenhouse Conditions. Agr. Sci. Tech., 18: 1091-1103.
38. Yebirzaf Y., B. Derbew and T. Kassaye, 2016. Physiological Responses of Different Tomato (*Solanum lycopersicum*) Varieties in Relation to Growth Conditions. Middle-East Journal of Scientific 24(9): 2904-2908.