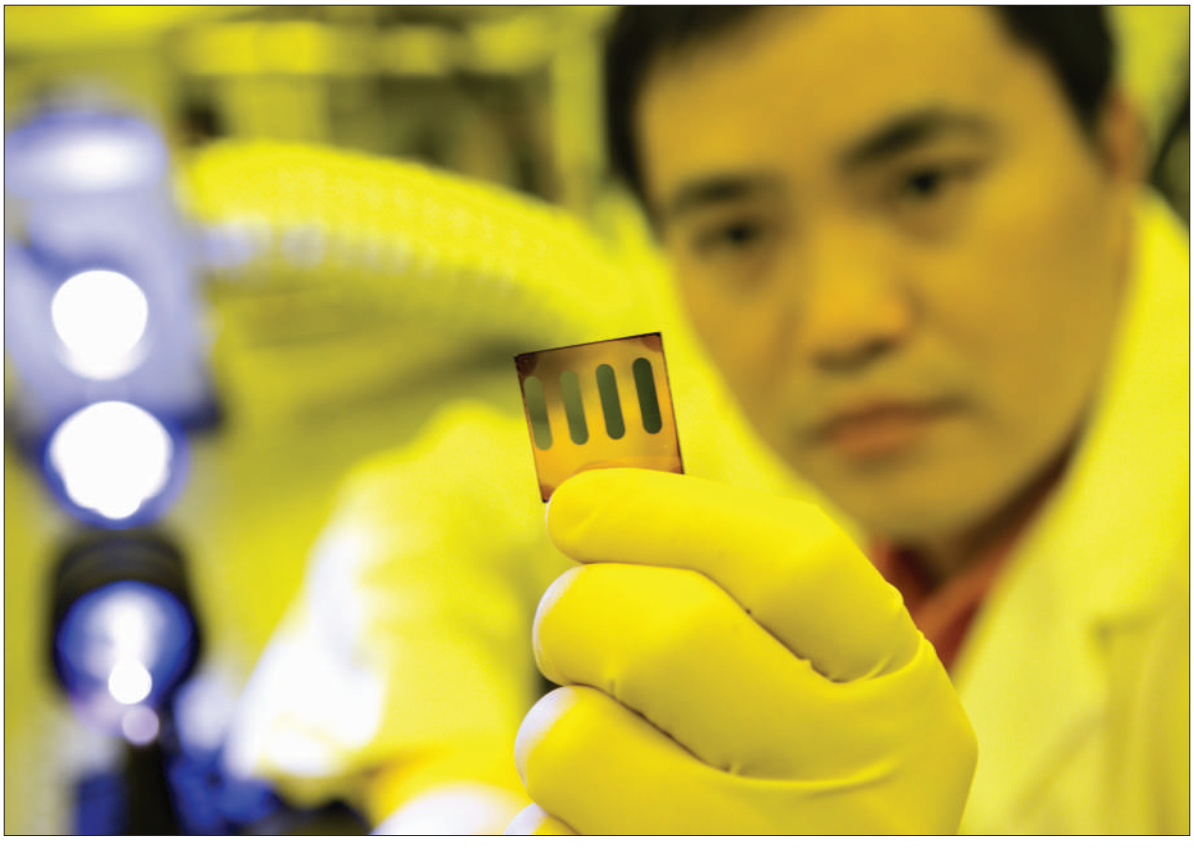

Singapore Journal of

Scientific Research

ISSN: 2010-006x

science alert

http://scialert.net/sjsr

Singapore Journal of Scientific Research 2 (2): 33-46, 2012
ISSN 2010-006x / DOI: 10.3923/sjsres.2012.33.46

Yield and Quality of Indeterminate Tomato (*Lycopersicon esculentum* Mill.) Varieties with Staking Methods in Jimma

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ABSTRACT

Different staking methods on yield and quality of indeterminate tomato varieties were examined in an experimental field under irrigation in Jimma University, Ethiopia. Staking methods used were: single post staking (T_1), single string (T_2), French type (T_3) and non-staking (T_0) and Randomized Complete Block Design (RCBD) with three replications. The result revealed; Miya with French type gave the highest number of flowers per plant (75.26). The highest fruit set was recorded from the same variety, while the three staking methods did not differ from each other but only differ from the non-staked. Highest number of marketable fruit was found from Miya with French type (27.53), the lowest was observed from the un-staked plants. Correlation coefficient strongly supported the positive relationship between the number of flowers with fruit set ($r = 0.95$) and a number of marketable fruit ($r = 0.71$). Highest unmarketable fruits were recorded from un-staked plants of Metadel (20.86), while lowest from a French type with Miya variety. Metadel with French type staking gave the highest marketable fruit yield (1.75 kg). Miya with non-staking had a lower marketable fruit yield as 0.64 kg. Miya variety was found to contain more sugar 4.64%. High percentage of late blight and fruit rot were recorded from control plots. The Blossom end rot was high in Miya and Metadel with un-staked plants. Higher profits were found from French type and single string with Metadel and Miya varieties. Least profit was obtained from non-staking. French type and single string staking could be recommended for better yield and quality of tomato.

Key words: Tomato varieties, yield, staking, horticultural production, cost and benefit analysis

INTRODUCTION

Fruit yield and quality are the important factors observed in production of tomatoes. Yield of tomatoes in the tropics is generally low compared to the temperate regions (Muhammad and Singh, 2007). Muhammad and Singh (2007) compared the average yield of tomatoes in Thailand as 9.9 t ha^{-1}, 15.6 in India, 25.3 in China, 8.8 in Philippines, 4.5 in Malaysia, 52.8 in Japan and 63.6 t ha^{-1} in U.S.A. with that of Africa average yield 8-25 t ha^{-1} which is the highest yield from South Africa and the least from Benin and Nigeria.

Tomato among vegetables, is known as a good source of vitamin A and C, income generating enterprise, provides employment in the production and processing industries, reduces prostate and lung cancer and lowers cholesterol in the blood (Karen Collins, 2007).

Quality tomato fruits, especially the physical appearance such as spotless fruits, uncracked fruits, uniform color and disease free fruits attract the attention of consumers. Some consumers like fruits with high acidity content while some preferred fruits with less acid content (Davies and Winsor, 1969). Oyenuga (1968) reported countries like Phillippines, Taiwan and Mexico grow tomato with supports to obtain earlier, clean and larger fruits.

Tomato variety is classified according to growth type, determinate and indeterminate varieties. Hanson *et al.* (2000) opined that determinate varieties do not require stakes as the indeterminate varieties because they continue to grow and produce fruit year round except they are killed by harsh weather like frost. This is one of the factors that made it necessary for indeterminate variety to be supported with local materials like woods or bamboo that can be afforded by both small and large scale farmers.

Staking increases fruit yield, reduces the proportion of unmarketable fruit and facilitates chemical spraying and harvesting (Kader and Morris, 1976). Staking produce high quality fruits and avoids fruits rot. It allows better aeration, reduces attacks of fungus diseases and ensures better exposure of the foliage to light for better photosynthesis (FAO, 2007). According to Ariyarathne (1989) recommended staking because it protects vegetables from animals, diseases and also provides good quality vegetables. Akoroda *et al.* (1990) and Trenbath (1976) supported the idea of staking because it facilitates harvesting of vegetables and pods and exposes the leaves for effective light reception.

Ariyarathne (1989) observed a highly significant yield differences among the staking methods, the non-staking treatment gave the lowest yield of 22.66 t ha^{-1}, the triangle method was 37.88 t ha^{-1}, the bench method recorded the highest yield of 41.89 t ha^{-1} and the single staking gave a significantly higher marketable yield than that of non-staking. The outcome of the experiment also revealed that the number of marketable fruits per bench method gave the highest number of marketable fruits, while the non-staking method gave the lowest number. Chadha (2001) reported that, training of tomato is required to produce better quality fruits. However, this study determined the effect of staking on yield and quality of Marglobe, Miya and Metadel indeterminate tomato varieties under Jimma condition in Ethiopia.

MATERIALS AND METHODS

The experiment was conducted in the Jimma University College of Agriculture and Veterinary Medicine, experimental field, Jimma, Ethiopia in October to April 2009/2010 cropping season under irrigation. The University College of Agriculture is located in the Oromia Region/State in the South Western part of Ethiopia, 343 km away from Addis Ababa, with an altitude of 1710 meters above sea level (m.a.s.l.), with latitude 7°42"N and longitude 36°50"E. The minimum and maximum temperatures were about 11.4°C and 26.8°C, respectively. The average annual rainfall was about 1500 mm. Although, BPEDORS (2000) stated that the annual rainfall was from April to October and had a relative humidity of 37.92 and 91.4% as minimum and maximum, respectively.

In this study, Marglobe, Metadel and Miya indeterminate tomato varieties were used with wood (*Eucalyptus camaldulensis*), locally made rope, polyethylene bags, cardboard paper and three different methods of staking. The staking methods included: single-post-staking, single-string-staking, French-type-staking and non-staking (control).

The field experiment conducted using a 3×4 Factorial arrangement in Randomized Complete Block Design (RCBD), consisted of two factors (staking methods and tomato variety) with three replications. The tomato varieties were randomly assigned in the experimental plots. The size of the

plot was 6.72 m^2 (2.4 m long×2.8 m wide per plot), 0.5 m space between plots and 1.5 m between blocks. A plot consisted of four rows with eight plants each, which made up a total of 32 plants per plot.

The seedlings were raised with names of each variety written on card board paper and fixed on well prepared beds against each variety to differentiate the varieties in the month of October. All agronomic practices were employed according to the recommendations of the Ethiopian Agricultural Research Organization (EARO, 2004). Seedlings were transplanted at 35 days after sowing with spacing 70×30 cm. Again, names of each tomato variety was written on card board paper and fixed on well prepared beds against each variety to differentiate the transplanted varieties. Fertilizer was applied at the rate of 200 kg ha^{-1} DAP and 150 kg ha^{-1} Urea. All the quantity of DAP fertilizer and 50% of Urea were applied at the time of transplanting and the other 50% of Urea was applied after half a month of transplanting. Proper water irrigation was applied as per recommended frequency and time (EARO, 2004).

Staking of tomato plants was done 30 days after transplanting by using woods (*Eucalyptus camaldulensis*) and string (locally made). The three methods of staking (single-post-staking, single-string-staking and French-type-staking) and non-staking (control) for comparison, were used. Woods of 3 cm thick and 175 cm tall were used for all the staking methods (FAO, 2007).

Single post staking: A pole of 175 cm height was fixed in the soil to 25 cm depth and 5 cm away from each plant and a string of 187 cm was carefully tied under the lower node of the plant loosely to avoid bruises to the stem which may cause infection to the plant. The string was wrapped around the pole, as the plant increased in height; the vines were trained by wrapping them on the string. When the primary branches developed and bear fruit, there was a need for more support due to weight; however, additional strings were used to support the plants.

Single string staking: A pole was fixed in to the soil, one at the extreme end of the opposite side of each row, a pole of 204 cm was placed across the two poles, at the meeting points between the two poles, a tie was made together with a string to hold them tight. This is to prevent any disturbance by wind or the workers around the plots. A string of 215 cm was used to tie under a leave node loosely and supported to the crossbar by wrapping the string two times and finally made a knot. However, as the plant increased in height and developed more branches with fruits, there was an increase in weight where by additional strings was used for more support.

French type staking: A pole of size 175 cm height and 25 cm width was deeply fixed in the soil between two plants in each row, as the plant grew to the height of 6 cm height, a string of 620 cm was used to support the plants from running on the ground. The string was wrapped on the first pole at the extreme end of each row, two twists were made and the strings were separated into two; one to the left hand side of the plant while the second string goes to the right to support the plants side by side. This process continued to the last pole at the other end of the row. The process was repeated four times in each row at 6 cm interval as the plant grows.

Non-staking (control plots): The non staking plots were left free to grow without staking.

Number of flowers per cluster: The number of flowers per cluster of the sample plants were counted and recorded. The sample plants 1-8 were tagged with coloured polythene bags to

differentiate them as: Blue = 1, White = 2, Pink = 3, Light blue = 4 Ash = 5, Black = 6, Yellow = 7 and Green = 8. Then, the clusters on each of the plants were again represented with coloured polythene bags by separating them into lower, middle and upper level clusters. The lower level was regarded as the first clusters produced by the plants within two weeks, followed by another two weeks as middle level and then the last level after weeks was upper level. In each level, clusters were tagged with different colours of polythene bags to differentiate the number of clusters of the sample in each plot as: Orange = A, Black = B, Pink = C, Blue = D, White = E, Yellow = F, White rope = G, Ash = H and Light yellow = I. The flowers were counted from each cluster of every level according to how they were tagged and recorded.

Statistical analysis: The data for this study were analysed using the Analysis of Variance (ANOVA) statistics to establish the Least Significant difference and the coefficient of variance on the effect of staking methods and varieties of tomato on the following variables titratable acidity (%), total soluble solid (°Brix), sugar acid ratio (%) and pH as well as their interaction effects. The effect of staking methods and varieties on disease incidence, physiological disorder and bird attack and the interaction effect of variety and staking methods on the number blossom-end-rot, fruit rot, birds and sunburn. Effects of staking on late blight disease on tomato as well as the Cost and returns of labor and materials for different staking methods were also found.

RESULTS AND DISCUSSION

Effect of staking methods on plant height and number of primary branches per plant: Analysis of variance indicated that, Marglobe variety with single post staking increased the plant height 158.69 and 103.55 cm than the Metadel variety with single string staking 74.40 cm, while Miya with French type staking had 81.94 cm. However, all the varieties with un-staked plants gave the low plant heights as 88.19, 60.59 and 46.29 cm, respectively (Table 1). This study seems to have higher plant height compared to the work of Valenzuela *et al.* (1993) who reported the highest plant height was 50.2 cm and the lowest plant height was 43.6 cm from an experiment conducted on vegetable cultivar trials in Hawaii. On the number of primary branches, Marglobe and Miya

Table 1: Effect of staking methods and variety on plant height and number of primary branches

Variety	Staking	Plant height (cm)	No. of primary branches
Marglobe	Non-staking	88.19^{bc}	6.37^{b}
	Single post staking	158.69^{a}	6.33^{b}
	Single string staking	103.55^{b}	7.08^{a}
	French type staking	89.95^{bc}	5.74^{c}
Metadel	Non-staking	60.59^{ef}	6.29^{b}
	Single post staking	68.77^{de}	6.46^{b}
	Single string staking	74.40^{cde}	6.25^{bc}
	French type staking	65.69^{de}	6.25^{bc}
Miya	Non-staking	46.29^{f}	6.46^{b}
	Single post staking	72.24^{cde}	6.71^{ab}
	Single string staking	71.01^{cde}	6.75^{ab}
	French type staking	81.94^{cd}	6.46^{b}
LSD 5%		19.08	0.51
CV (%)		4.16	4.73

LSD: Least significance difference, CV: Coefficient of variance, Values having common letter(s) in a column do not differ significantly at 5% level

varieties with a single string and single post staking gave a significant number of primary branches as 7.08, 6.75 and 6.71, but the French type staking with Marglobe variety reduced the number of primary branches 5.74. However, there was no significant difference between Metadel variety with the staking methods on the number of primary branches (Table 1). The tallest plant height observed from all the varieties with the staking methods, could be that, almost every leaf of the plant received sunlight for photosynthesis since the plants were upright supported by staking than the control plants that were left compacted on the ground.

Effect of staking methods on number of flowers and fruit set per cluster: Among the staking methods, The French type staking with Miya variety gave the highest number of flowers 75.26 and fruit set per cluster 63.86. The un-staked plants had the lowest number of flowers 58.65 with a low number of fruit set per cluster 45.27 (Table 2). The results are further supported by a positive and very highly significant correlations between the number of flowers per cluster with fruit set per cluster r = 0.95. Probably the staking methods might have influenced the plant height as the plants were raised and supported by staking which may allow the leaves to get access to light for photosynthesis and in turn, favored the number of branches and trusses as well as producing more flowers.

Effect of staking methods on number of marketable and unmarketable fruits per plant and total number of fruit: Miya variety with French type staking increased the number of marketable fruits 36.96 more than Miya with single string staking 28.62, which is not significantly different with single post staking 25.99. All the varieties with un-staked plants decreased the number of marketable fruits per plant as 13.79, 11.49 and 18.54, respectively. Similarly, the un-staked plants had the highest number of unmarketable fruits per plant 29.75, 21.66 and 20.66, respectively. However, the varieties with all the staking methods gave the least number of unmarketable fruits 19.08 to 13.17. The result further strengthened by a negative and significant correlation between the number of unmarketable and marketable fruits r = -0.68**. Table 3 On the total number of fruits, Miya variety with French type staking gave the highest total number of fruits 50.13 and the lowest total number of fruits was recorded from Marglobe variety with all the staking methods 39.87 to 33.79 Table 3. The low number of fruits recorded from

Table 2: Effects of staking methods and varieties on numbers of flowers and numbers of fruit set per cluster

Parameter	No. flower per cluster	No. fruit set per cluster
Staking		
Non-staking	58.65^{c}	45.27^{b}
Single post staking	70.67^{ab}	59.34^{a}
Single string staking	67.3^{ab}	56.58^{a}
French type staking	73.62^{a}	61.53^{a}
LSD (5%)	4.02	7.69
Variety		
Marglobe	63.73^{b}	49.45^{b}
Metadel	63.72^{b}	53.73^{b}
Miya	75.26^{a}	63.86^{a}
LSD (5%)	3.48	6.66
CV (%)	6.08	14.13

Values having common letter (s) in a column (i.e., a, ab, etc.) do not differ significantly at 5% level

Table 3: Effect of staking methods and variety on fruits

Variety	Staking	No. of marketable fruit/plant	No. of unmarketable fruits/plant	Total number of fruits
Marglobe	Non-staking	13.79^{f}	20.92^{b}	34.71^{d}
	Single post staking	19.67^{e}	14.29^{def}	33.96^{d}
	Single string staking	18.04^{e}	15.75^{def}	33.79^{d}
	French type staking	20.11^{de}	19.50^{bc}	39.87^{bc}
Metadel	Non-staking	11.49^{f}	29.75^{a}	41.24^{b}
	Single post staking	20.21^{de}	19.08^{bc}	39.29^{bc}
	Single string staking	3.57^{cd}	17.25^{cde}	40.82^{b}
	French type staking	18.38^{e}	17.37^{cd}	35.75^{cd}
Miya	Non-staking	18.54^{e}	21.66^{b}	40.21^{b}
	Single post staking	25.99^{bc}	17.37^{cd}	43.36^{b}
	Single string staking	28.62^{b}	14.17^{ef}	42.79^{b}
	French type staking	36.96^{a}	13.17^{f}	50.13^{a}
LSD 5%		3.63	3.10	4.34
CV (%)		10.7	9.96	6.46

Values having common letters(s) in the same column do not differ significantly at 5%

Marglobe variety could be as a result of it's fruit size. The fruits were large, for the fact that, a single fruit from the first truss weighed 70 g; this could cause the less number of fruits from the variety as reported by Prudent *et al.* (2009).

The variation in the number of marketable fruits among the staking methods could be due to the incidence of late blight, fruit rot diseases that occurred as a result of high soil moisture caused by frequent rainfall that seriously affected the fruits of the non staked plots. In addition, birds significantly affected the fruits at pink and red ripe stages in all the staking methods as well as the un-staked plants. Birhanu and Tilahun (2010) found that, small animals and birds have interest in tomato. Miya variety with all the staking methods was highly affected by blossom end rot. The fruits might have suffered from Calcium deficiency (Nzanza, 2006). Defoliation caused by late blight (*Phytophthora infestans*) disease led to exposure of fruits to sunlight that rendered the fruits to sun scorched. This study agreed with the work of Ariyarathne (1989) and Maboko (2006) who reported that, a high significant marketable fruits was obtained from bench method 41.89 t ha^{-1}, and triangle 37.88 t ha^{-1} method than the yield observed from un-staked plants 22.66 t ha^{-1}.

Effect of staking methods on marketable, unmarketable and total yield per plant: The results on the marketable and unmarketable yield showed that, Metadel variety with French type staking increased the yield as 83.63 t ha^{-1}, however, the lowest yield was recorded from un-staked plants with Miya variety 30.60 t ha^{-1}. The un-staked plants of all the varieties, especially Metadel variety decreased the yield of fruits by high yield of unmarketable fruits 83.31 t ha^{-1} compared to the French type staking that gave less yield of unmarketable fruits 18.99 t ha^{-1} than the single post and single string staking (Table 4). However, Metadel with un-staked plants had the highest total yield of 137.97 t ha^{-1} and the lowest total fruit yield was observed from Miya with un-staked plants. FAO (2007) indicated that staking protects tomato fruits from disease and provides good quality tomatoes. Staking can increase fruit yield as reported by Kader and Morris (1976). Godfrey-Sam-Aggrey and Assefa Aytenfsu (1985) reported an increased yield of 6.5 tons from Heinz 1350. Similarly, Dessalegne (2002) reported the highest yields of 58.3 and 57.3 t ha^{-1} from staked tomato plants compared to 39.9 and 33.4 t ha^{-1} from un-staked plants. This study indicated that, staking might have protected the fruits from more damaged. Egun (2007) also

Table 4: Effect of staking methods and variety

Variety	Staking	Marketable fruit yield (t ha^{-1})	Unmarketable fruit yield (t ha^{-1})	Total yield (t ha^{-1})
Marglobe	Non-staking	62.18^{cde}	50.37^{b}	112.56^{cd}
	Single post staking	62.82^{cd}	33.64^{e}	96.47^{fg}
	Single string staking	69.36^{bc}	39.06^{cd}	108.42^{de}
	French type staking	72.14^{b}	40.64^{b}	119.78^{bc}
Metadel	Non-staking	54.66^{f}	83.31^{a}	137.97^{a}
	Single post staking	61.79^{def}	40.99^{c}	102.78^{ef}
	Single string staking	68.12^{bcd}	35.60^{de}	103.72^{ef}
	French type staking	83.63^{a}	38.66^{cd}	122.29^{b}
Miya	Non-staking	30.69^{g}	45.99^{b}	76.69^{i}
	Single post staking	75.20^{b}	34.39^{de}	109.59^{de}
	Single string staking	54.92^{ef}	31.07^{e}	85.99^{h}
	French type staking	75.12^{b}	18.99^{f}	94.12^{g}
LSD 5%		7.30	4.92	8.02
CV (%)		6.71	6.98	4.47

Values having common letters(s) in the same colnmn do not differ significantly at 5%

Table 5: Effects of staking methods and variety on fruit length, fruit diameter and fruit shape index

Variety	Staking	Frnit length (cm)	Frnit diameter (cm)	Frnit shape index
Marglobe	Non-staking	5.53^{cd}	4.43^{bc}	1.26^{bc}
	Single post staking	5.60^{cd}	4.23^{c}	1.32^{b}
	Single strnig staking	6.66^{a}	4.16^{c}	1.60^{a}
	French type staking	5.73^{bc}	4.73^{ab}	1.21^{bcd}
Metadel	Non-staking	5.43^{cd}	5.13^{a}	1.06^{ef}
	Single post staking	5.43^{cd}	5.01^{a}	1.06^{def}
	Single strnig staking	5.76^{bc}	5.06^{a}	1.14^{cde}
	French type staking	6.13^{b}	4.83^{a}	1.27^{bc}
Miya	Non-staking	4.50^{e}	5.10^{a}	0.88^{g}
	Single post staking	5.23^{d}	4.23^{c}	1.23^{bc}
	Single strnig staking	4.56^{e}	4.80^{ab}	0.95^{fg}
	French type staking	4.76^{e}	4.80^{ab}	1.00^{efg}
LSD 5%		0.42	0.47	0.15
CV (%)		4.59	5.90	7.60

Values having common letter(s) in a column do not differ significantly at 5% level

reported 500.0 to 500.5 g as leaf marketable yield from staked plants and 498.3-499.5 g from un-staked plants (pumpkin). Diseases and physiological disorder mostly affected un-staked plants, whereas birds and unidentified animals widely affected both the staked and un-staked plants. However, this observation is line with the works of Kader and Morris (1976), Ariyarathne (1989), FAO (2007) and Dessalegne (2002).

Effect of staking methods and varieties on fruit length fruit diameter and fruit shape index: Marglobe with single string staking increased the fruit length 6.66 cm; followed by Metadel that had 6.13 cm and Miya with un-staked had the lowest fruit length. In terms of fruit diameter, there was no significant difference between Metadel variety with all the staking methods and Miya with un-staked plants, single string and the French type staking. The fruits obtained from the above mentioned varieties and the staking types had the highest diameters (5.13 to 4.80 cm) as observed in Table 5. However, the lowest fruit diameters were recorded from Marglobe variety with single string staking as 4.16 cm and Miya variety with single post staking 4.23 cm. On

the fruit shape index, Marglobe had the highest as 1.60 followed by same variety with single post staking 1.32 and the least fruit shape index were recorded from Miya variety 0.95 to 0.88 as in Table 5. The differences in shape index could be genetical as reported by Brewer *et al.* (2007).

Effect of staking methods on pericarp thickness: Miya variety had the thickest pericarp of 0.29 mm. Metadel had 0.23 mm thickness and Marglobe variety with 0.212 mm (Fig. 1). Staking could have effect on the pericarp thickness of the tomato varieties or the differences in the pericarp thickness could be genetic.

Effect of staking methods and varieties on root, fruit and stem dry matter content: Miya variety irrespective of staking methods gave high dry matter ranging from 18.83 to 20.70 g plant^{-1} and statistically similar (Table 6). Metadel varieties with all the staking methods were statistically similar in low root dry matter (13.06 to 11.04 g plant^{-1}). On the fruit dry matter, Marglobe variety with French type method gave high dry matter 52.27 g plant^{-1}. However Metadel and Miya varieties with un-staked plants had low dry matter 16.40 and 17.11 g plant^{-1}. The result of the stem dry matter indicates that, Metadel with single post staking had the highest stem dry matter, 79.37 g plant^{-1}. Low stem dry matter was observed from Marglobe with single string staking 29.23 g plant^{-1} and Miya with un-staked plants (Table 6). The root dry matter seems to be lower than the fruits and stems. Probably, the partition of the nutrient to the roots, fruits and stem

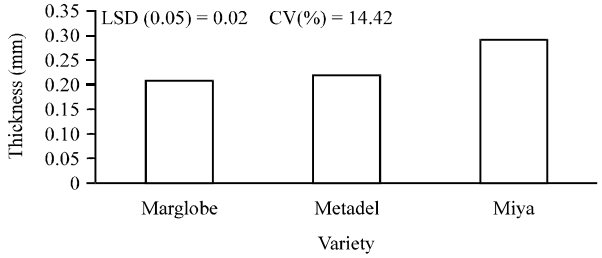

Fig. 1: Response of varieties to fruit pericarp thickness

Table 6: Interaction effect of different staking on dry matter distribution of the plants

Variety	Staking	Root dry matter (g plant^{-1})	Fruit dry matter (g plant^{-1})	Stem dry matter (g plant^{-1})
Marglobe	Non-staking	10.17^{b}	41.55^{b}	61.01^{b}
	Single post staking	17.19^{a}	32.62^{ef}	50.71^{c}
	Single string staking	19.60^{a}	40.24^{bc}	29.23^{e}
	French type staking	13.27^{b}	52.27^{a}	61.68^{b}
Metadel	Non-staking	11.04^{b}	16.40^{g}	39.59^{d}
	Single post staking	11.89^{b}	39.56^{bcd}	79.37^{a}
	Single string staking	12.52^{b}	34.66^{de}	45.25^{cd}
	French type staking	13.06^{b}	29.11^{g}	42.32^{d}
Miya	Non-staking	20.70^{a}	17.11^{g}	28.75^{e}
	Single post staking	20.70^{a}	43.58^{b}	30.19^{e}
	Single string staking	18.83^{a}	35.75^{cde}	42.19^{d}
	French type staking	18.50^{a}	32.51^{ef}	48.46^{c}
LSD 5%		3.81	5.04	6.10
CV (%)		14.42	8.60	7.73

Values having common letter(s) in a column do not differ significantly at 5% level

was not equal. Cockshull and Ho (1995) reported that, fruits are the strongest sinks for assimilate in tomato; whereas stems and roots are weaker sinks of assimilate Cockshull and Ho (1995). Heuvelink (1996) revealed 58-60% dry matter were found in fruits and 43% from double-shoot treatments. From the report of Cockshull and Ho (1995) which says, fruit are strongest sinks for assimilate in tomato plant seems to be contradictory with this study, because the stem of Metadel had the highest dry matter than the fruit, although, the result obtained from the fruit dry matter seems to agree with (Heuvelink, 1996).

The difference between the fruit and stem dry matter could be influenced by the size of the fruits at the time were harvested. The fruits were harvested after the sixth harvest when the fruit were small, this size could influence the assimilation of more carbohydrate from the source.

Effect of staking methods and varieties on titratable acidity total soluble solid sugar acid ratio and pH: The combined effects of variety and staking method showed that, Metadel and Marglobe with un-staked plants had high acid 1.02 and 1.00% than the Metadel French type staking 0.92% and Marglobe with single post single string staking 0.96 and 0.53%, Table 7. Wahundeniya *et al.* (2006) reported the percentage of acid of some varieties of tomato tested; ranges from 0.78-0.97. Marglobe irrespective of the staking treatment had high TSS (3.80 to 3.56 °Brix) than Miya and Metadel varieties with all the staking methods Table 7. Miya with un- staked plants and French type staking gave the highest sugar to acid ratio of (4.86%) and (4.66%), respectively (Table 7). However, the minimum sugar acid ratio was obtained from Metadel with single post and single string methods (3.13%) Table 7. On the pH, Marglobe with French type staking method had high pH of 4.86, followed by Miya and Metadel varieties with all the staking methods but statistically similar (Table 7). Among the researchers, Davies and Winsor (1969) revealed that, the lesser the water content in fruits, the more sour is the fruit. However, the acid content of tomato dependent on the stage of harvest and the consumer preference, some people preferred fruits with high acidity while others like fruits with less acid, high sugar and flavor. Another report revealed that, water deficit increase fruit soluble solid level (Mitchell *et al.*, 1991). Maboko (2006) confirmed that, frequency of water supply affect yield and fruit quality.

Table 7: Interaction effects of staking methods and variety on titratable acidity, total soluble solid, sugar acid ratio and pH

Variety	Staking	Titratable acidity (%)	Total soluble solid (°Brix)	Sugar acid ratio (%)	pH
Marglobe	Non-staking	1.00^{a}	3.70^{ab}	3.46^{ef}	4.20^{d}
	Single post staking	0.91^{c}	3.60^{abc}	4.10^{d}	4.20^{d}
	Single string staking	0.53^{e}	3.56^{abc}	4.40^{c}	4.53^{bc}
	French type staking	0.96^{abc}	3.80^{a}	3.26^{fg}	4.86^{a}
Metadel	Non-staking	1.02^{a}	3.43^{cd}	3.53^{e}	4.46^{bcd}
	Single post staking	0.98^{ab}	3.10^{e}	3.13^{g}	4.26^{cd}
	Single string staking	0.98^{ab}	3.06^{e}	3.13^{g}	4.40^{bcd}
`	French type staking	0.92^{bc}	3.40^{cd}	3.66^{e}	4.23^{cd}
Miya	Non-staking	0.74^{d}	3.46^{c}	4.86^{a}	4.36^{bcd}
	Single post staking	0.74^{d}	3.10^{e}	4.50^{bc}	4.63^{ab}
	Single string staking	0.74^{d}	3.20^{de}	4.53^{bc}	4.40^{bcd}
	French type staking	0.70^{d}	3.00^{e}	4.66^{ab}	4.23^{cd}
LSD 5%		0.06	0.24	0.26	0.31
CV (%)		4.34	4.22	3.92	4.16

Values having a common letter(s) in a column do not differ significantly at 5% level

Wahundeniya *et al.* (2006) reported TSS found, ranges from 4.92-5.07 °Brix. MARD (2005) reported the TSS recorded from Miya was 4.0% and that of Metadel was 4.4%. However, there is no significant difference between the TSS found among the varieties tested with all the staking methods. This implies that, staking methods influenced the TSS.

Nzanza (2006) recorded the pH of two varieties as 4.16 and 4.08 from research work conducted on yield and quality of tomato as influenced by Ca, Mg and K nutrition. However, Wahundeniya *et al.* (2006) found no significant different in pH among the varieties of tomato grown under controlled environment. MARD (2005) reported the pH of Miya as 4.5 and that of Metadel 4.7 somehow higher than the results of the present study Table 7.

Effect of staking methods and varieties on disease incidence, physiological disorder and bird attack: The un-staked plants had the maximum LB 1.34%, followed by French type staking 1.10%. The minimum incidence was recorded from single string staking 0.54%. The variations observed on the LB incidence on the staking methods especially the French type staking, could be because the rope supported the plants side by side brought the branches close to each other and due to high density of plants might have hindered free penetration of air and light to dry the moisture after rain and high humidity. Fruits produced by the un-staked plants were in contact with wet soil that caused high LB incidence than the staked plants. This implies that, staking is necessary for tomato Fig. 2.

The results on disease incidence showed that, Metadel variety with un-staked plants (1.25%) BER incidence and Miya with all the staking methods were highly affected by same disease (0.86 to 1.28%) Table 8. In conclusion, since Miya with all the staking methods were affected by BER, this means, the variety could be susceptible to BER due to Ca deficiency (Nzanza, 2006). For the fruit rot incidence, all the three varieties with un-staked had high percentage of fruit rot than the staking methods Table 8.

All the varieties with the staking methods as well as the un-staked plants were significantly affected by Birds incidence (12.11 to 14.88%) Table 8. Birhanu and Tilahun (2010) reported that, small animal and birds fed more on Melka salsa and Marglobe than Melka Shola cultivar; but this study showed that, the small animals and birds were interested on all the cultivar used (Marglobe, Metadel and Miya). This means, small animals and birds like tomato regardless of the cultivar and observation, staking have no effect on them.

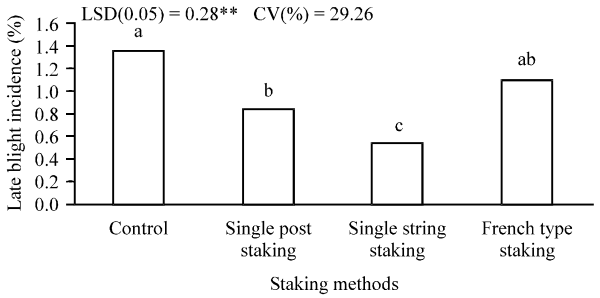

Fig. 2: Effects of staking on late blight disease on tomato, The different alphabets on each bar showed the degree of late blight disease effect on the staking type, **Significant at p = 0.01

Table 8: Interaction effect of variety and staking methods on the number blossom-end-rot, fruit rot, birds and sunburn

Variety	Staking	Blossom end rot	Fruit rot	Birds	Sun burn
Marglobe	Non-staking	0.53^{e}	1.16^{a}	14.88^{a}	1.13^{a}
	Single post staking	0.00^{f}	0.00^{c}	14.88^{a}	0.00^{d}
	Single string staking	0.00^{f}	0.00^{c}	14.88^{a}	0.00^{d}
	French type staking	0.00^{f}	0.00^{c}	13.88^{a}	1.02^{ab}
Metadel	Non-staking	1.25^{ab}	1.22^{a}	13.49^{a}	1.20^{a}
	Single post staking	0.00^{f}	0.00^{c}	16.27^{a}	0.70^{bc}
	Single string staking	0.00^{f}	0.14^{b}	14.88^{a}	0.00^{d}
	French type staking	1.11^{bc}	0.14^{b}	13.50^{a}	0.42^{c}
Miya	Non-staking	1.28^{a}	1.23^{a}	12.11^{a}	1.16^{a}
	Single post staking	0.81^{d}	0.00^{c}	13.49^{a}	0.00^{d}
	Single string staking	0.86^{d}	0.00^{c}	14.00^{a}	1.02^{ab}
	French type staking	1.05^{c}	0.00^{c}	14.55^{a}	0.00^{d}
LSD 5%		0.15	0.09	4.82	0.33
CV (%)		1.87	15.98	21.63	35.34

Values having common letter(s) in a column do not differ significantly at 5% level

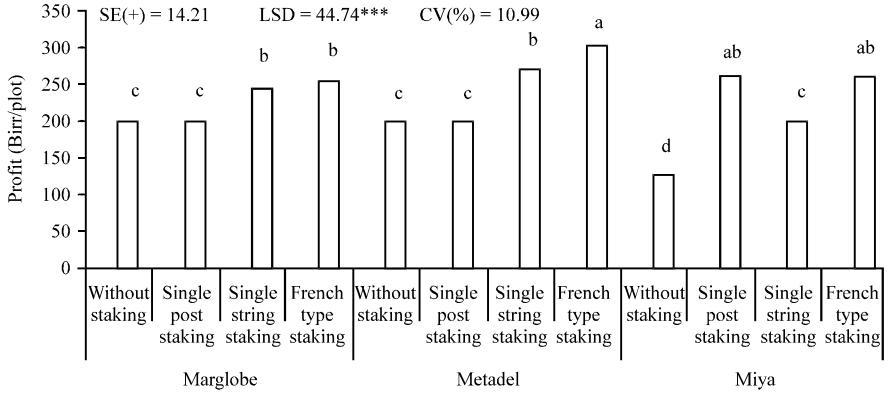

Fig. 3: Cost and returns of different staking methods. The letters on each bars (i.e., a, b, ab, etc.) explains the significant difference in terms of cost and returns on the staking methods and the tomato varieties, ***Significant at 0.01

The effects of sunburn on all the varieties with non-staking were higher than the staked plants (Table 8). The incidence of the sunburn could be due to defoliation by Late blight (*Phytophthora infestans*) that led to the exposure of fruits to sun light. However, it could be recommended that French type staking method and single string staking could be used in Jimma condition if more spacing and less number of plants per row are used to allow free penetration of air after rainy, easy access of weeds and free movement in order to reduce the incidence of late blight.

Cost and returns of labor and materials for different staking methods: Metadel variety with French type staking gave the highest profits of 301.54 birr per plant, Miya with single post and French type staking 268.44 Birr per plant. Marglobe and Metadel with non-staking method had low profit of 197.14 birr, which was not significantly higher than single post staking 193.94 Birr. A that time, a kilo of tomato was sold at 6 Birr, therefore, the income accrued from non-staking method amounted to 357.60 Birr, single post staking = 336.60 Birr, single string staking 357.60 Birr and French type staking gave 365.60 Birr (Fig. 3). This study suggests that French type and single

string staking should be introduced to farmers based on the staking types that support the plants and couple with the high density of plants that hinder free penetration of air and light to dry the moisture after rain and high humidity. The methods also gave high returns and reported as the cheapest methods of staking tomato plants by Ariyarathne (1989), Saunyam and Knapp (2003) in their study on pruning and trellised that led to additional profits.

CONCLUSION

Disease and pests are the constraints of tomato producers all over the world including Ethiopia. A field study was conducted to study the effect of different staking methods on yield and quality of indeterminate tomato (*Lycopersicon esculentum* Mill.) varieties under Jimma condition, in the experimental field of College of Agriculture and Veterinary Medicine, Jimma University. Miya, Marglobe and Metadel varieties were used while the staking methods were single post staking, single string staking, French type staking and the non- staking as the control. Data collected were subjected to Analysis of variance, means separation was conducted where mean of variety and, staking were found significant and no interaction and correlation coefficient was conducted among the parameters. The result showed that Miya variety had recorded significantly highest number of flowers than Marglobe and Metadel, both of which were not significantly different from one another.

The results were further supported by a strong positive correlation between the number of flower per cluster and fruit set per cluster ($r = 0.95$), number of marketable fruits ($r = 0.71$). There was significant difference in the number of fruits set per cluster due to variety and staking.

The interaction effect between the staking methods and varieties on the number of marketable fruits was highly significant ($p<0.001$). Similarly, the number of unmarketable fruit showed interaction effect between the staking methods and variety ($p<0.0001$). However, the number of fruits had a positive correlation with the number of marketable fruits ($r = 0.66$), but negative correlation with the number of unmarketable fruits ($r = -0.531$). Number of marketable fruits, therefore, was negatively correlated with the number of unmarketable fruits at ($r = -0.679$). This imphes that when the number of marketable fruits decreases, the number of unmarketable fruits increases. Similarly, the staking methods and varieties interacted significantly ($p<0.001$) on the number of unmarketable fruits yield. The number of marketable fruits was found to be negatively correlated with unmarketable fruit yield ($r = -0.767$), and the number of unmarketable fruit was positively correlated with unmarketable fruit yield at ($r = 0.904$). Plants gave a significant number of fruits set but was affected by too much rain that brought about fruit rot disease and blossom end rot. Birds significantly destroyed the fruits which lowered the number of marketable fruits as well.

Cost and returns of different staking and labor showed that, French type staking gave the highest profit as 301.54 Birr followed by single string staking as 268.44 Birr, while the least profit was recorded from non-staking and single post staking 195.44 and 195.78 Birr, respectively.

In conclusion therefore, the easiest method of reducing tomato disease incidence is by using French type and single string staking that cost less and give higher yields and good quality fruits than single post and non-staking. Economically, the two methods could be suggested to farmers as the cheapest methods of staking.

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