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Tomato (*Solanum lycopersicum* L.) Yield and Fruit Quality Attributes as Affected by Varieties and Growth Conditions

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Abstract: Tomato is one of the most widely eaten vegetable in the world and ranks first as a processing vegetable. Tomato production in Ethiopia is, however, far below the average productions observed in some other countries and the fruits are with poor quality. Adopting technologies like greenhouse, on the other hand, promote year round tomato production and improve fruit quality. This study evaluated yield and quality attributes of four different tomato varieties both under greenhouse or open field conditions. The experiment was conducted at Jimma University College of Agriculture using four different varieties being arranged in RCBD. The study in general indicated that growing tomato under greenhouse conditions increased yield by 54% and improved quality attributes than open field conditions. Among varieties, Marglobe, Moneymaker and Bishola were observed as promising varieties in both growing conditions. Studies that included other varieties and agronomical practices are needed to further substantiate the conclusion.

Key words: Marketable yield · Titrable acidity · Shape index · Moneymaker · Total soluble solids

INTRODUCTION

Tomato is the third largest vegetable crop after potato and sweet potato and as a processing crop it ranks first among all vegetables [1]. China is the biggest tomato producer in the world with annual production 34.1 million tons [2]. In Ethiopia the area coverage by tomato was 4, 953 ha and production in tons was 40,426 with the productivity of 6.2 ton ha^{-1} in 2015 [3]. However, the total production and productivity in Ethiopia is far below than the average of major producers in Africa [4]. Among many contributing factors, improper management of environmental factors (rainfall, frost, temperature and relative humidity) or season dependency is major problems which contribute to shortage of fresh tomato fruit to the local and international market [5, 6]. Uneven rainfall conditions of the country also limit tomato production to few months only. This results in shortage of fresh tomato fruit in the local markets and reduces incomes of the producers that relay on the crop for their livelihood. The market values of tomatoes are also determined by fruit quantity and quality [7]. Field grown fruits, however, can be coated with soil or dust particles and affect quality and shelf life of the fruits [8].

To promote year round tomato production and improve fruit quality of the country, growing tomato in protected environment (greenhouse) is one possible option. Adopting greenhouse tomato production in the country, allows growers to maximize their tomato crop production, keep the fruits free of disease and insect pests [9]. So far no research has been done to evaluate quantity and quality of fruit grown in greenhouse and open sun. In addition, no varieties were screened for protected cultivations system. In view of this, four tomato (*Solanum lycopersicum* L.) varieties namely: Bishola, Eshet, Marglobe and Moneymaker were evaluated inside greenhouse and open field for fruit yield and quality at Jimma university college of agriculture and veterinary medicine (JUCAVM) during 2011/2012 cropping season.

MATERIALS AND METHODS

The experiment was conducted at Jimma University College of Agriculture and Veterinary Medicine, newly

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Table 1: List of varieties and their description

Variety name	Year of release	Growing altitude (m asl)	Growth Habit	Maturity Days (d)	Research Yield (q/ha)
Eshete	2005	700-2000	Indeterminate	75-80	394
Moneymaker	1980	700-1800	Indeterminate	110-120	300
Marglobe	1976	700-2000	Indeterminate	100-110	320
Bishola	2005	500-2000	Determinate	85-90	340

Source: MoARD, [14].

built greenhouse and open field in the year 2011/2012 cropping season under irrigation. The site is located at 70, 33' N latitude and 360, 57' E longitude at an altitude of 1710 m.a.s.l. The area receives an annual rainfall of 1500 mm. The mean maximum and minimum temperatures were, respectively 26.8 °C and 11.4 °C. The mean maximum and minimum relative humidity of the study site were also 91.4% and 39.92%, respectively [10].

Four improved tomato varieties namely Eshet, Marglobe, Moneymaker and Bishola obtained from Melkassa agricultural research center were used for both greenhouse and open field experiment (Table 1). In both experimental conditions, the treatments were arranged in a Randomized Complete Block Design (RCBD) with three replications. Seedlings were raised in nursery bed and transplanted to the actual field at a spacing of 30 cm between plants and 70 cm between rows. All agronomic managements were adopted following previous recommendations [11]. Data on growth and physiological variables were collected from the middle twelve plants and subjected to ANOVA using SAS vr.9.2 [12]. Mean separation was carried out using LSD (Least Significant Difference) test at 5% level of significance [13].

RESULTS AND DISCUSSION

The results of this study indicated that number of fruits per cluster differed significantly *($p< 0.05$)* among tomato varieties. Difference in growing conditions, on the other hand, had no any effect on number of fruits per cluster (Table 2). Variety Moneymaker and Marglobe, respectively produced 7.28 and 6.84 fruits per cluster. Number of fruits per cluster is one of the major criteria to select better variety for yield. In this study, number of fruits per cluster was positively and strongly correlated ($r = 0.81^{**}$) with number of flowers per cluster. This indicates that the differences among the varieties observed in this study were therefore due to the highest number of flowers per cluster and the success of these flowers to develop to fruits.

Unlike number of fruits per cluster, number of fruits per plant was affected by both growth conditions and tomato varieties (Table 2). Number of fruits per plant was higher in greenhouse than in open field. Among varieties, Moneymaker gave the highest number of fruits per plant (46.4) than any other tomato varieties. Tomato plants in greenhouse have grown vigorously and had tallest plant height compared to those grown in open sun [15]. Also the results indicated that the number of fruits per plant was strongly and positively correlated ($r = 0.36^{*}$) with plant height and leaf area ($r = 0.69$). This vigorous growth with taller plant height and larger leaf area resulted to more number of flower cluster per plant and larger number of fruits per plant. This result is in agreement with findings reported by Yebrzaf *et al*. [15]. The authors reported larger mean number of fruits per plant for tomato plants grown in greenhouse than in open field.

Growing conditions did not affect average fruit weight per plant. Differences in average fruit weight per plant *($p<0.01$)*, on the other hand, was observed among tomato varieties grown in greenhouse. In this growing condition, variety Bishola produced fruits with average weight of 139.2 g per plant being followed by Eshet (130.0 g) and Marglobe (123.6 g). The lowest fruit weight per plant was found in variety Moneymaker. This is probably due to larger number of fruits per cluster and per plant that was observed in this variety. As the number of fruits per plat increases, competition among the fruits increase and fruits cannot grow to their full size and weight. Jones [8] reported similar findings and concluded that fruit number negatively correlated with fruit weight.

Number of fruit harvests varied significantly ($p < 0.001$) among tomato varieties grown under greenhouse (Table 2). Variety Marglobe and Bishola had a total of 12 to 13 pickings while in open sun these total fruits were harvested in a maximum of five to six rounds. Regardless of growing conditions, Ganesan and Subashini [17] reported a total of nine harvestings while, Pandey *et al*.[18] reported more fruit harvests in greenhouse than in open field growing conditions. In addition to the variability in growing conditions, these differences could closely be associated with variability in the genetic makeup of the varieties. Harvesting number was also found to positively and strongly correlated with plant height ($r = 0.79^{**}$), number of flowers per cluster ($r = 0.69^{**}$), number of fruits per cluster ($r = 0.72^{**}$) and fruit number per plant ($r = 0.66^{*}$).

Table 2: Number of fruits per cluster, number of fruit per plant, average fruit weight and number of harvests of tomato varieties grown under green house climate and open field

	Number of fruits per cluster		Number of fruit per plant		Average fruit weight (g)		Number of fruit harvests	
Varieties	Green house	Open field	Green house	Open field	Green house	Open field	Green house	Open field
Bishola	4.75[b]	5.37	26.11[c]	21.83[b]	139.20[a]	133.24	6.66[c]	4.00
Eshet	5.73[ab]	4.37	26.32[c]	14.41[c]	130.02[a]	103.56	10.66[b]	3.66
Marglobe	6.84[a]	5.45	35.47[b]	17.52[bc]	123.60[a]	140.01	12.66[a]	5.00
Moneymaker	7.28[a]	4.76	46.36[a]	31.91[a]	94.72[b]	99.23	12.33[a]	5.33
LSD (5%)	1.91	NS	5.41	5.12	34.25	NS	1.29	NS
CV (%)	15.52	12.20	8.06	11.67	14.36	17.20	6.09	15.27

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

Table 3: Total fruit yield per plant, total fruit yield per hectare and marketable fruit yield per hectare of tomato varieties grown under green house climate and open field

	Total fruit yield (g plant^{-1})		Total fruit yield (t ha^{-1})		Marketable fruit yield (t ha^{-1})	
Varieties	Green house	Open field	Green house	Open field	Green house	Open field
Bishola	1814.40[c]	1501.30[a]	86.40[c]	71.49[a]	65.32[c]	46.04
Eshet	1898.36[bc]	1115.30[b]	90.9[bc]	53.10[b]	68.33[bc]	33.83
Marglobe	2144.10[a]	1314.40[ab]	102.10[a]	67.30[ab]	72.10[a]	38.42
Moneymaker	2023.36[ab]	1494.50[a]	96.35[ab]	71.16[a]	69.80[ab]	45.91
LSD (5%)	159.730	330.950	7.606	15.757	3.757	NS
CV (%)	4.05	11.99	4.05	11.99	2.72	14.06

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

The statistical analysis in this study indicated that both growing conditions *(p<0.01)* and tomato varieties *(p<0.05)* significantly affected total fruit yield per plant and also per hectare. Total fruit yield per plant in the greenhouse ranged from 1898 to 2144 g per plant, while the corresponding figure in open sun was from 1115 to 1505 g per plant. Among varieties, variety Marglobe and Moneymaker grown in greenhouse had the highest total fruit yield per plant. In open field the highest yield was obtained from Bishola and also from Moneymaker. Similarly, total fruit yield per hectare ranged from 86 to 102 and 53 to 71 t/ha, respectively for greenhouse and open field growing conditions (Table 3).

Total fruit yield was positively and strongly correlated with plant height ($r = 0.62^{*}$), number of flowers per cluster ($r = 0.84^{***}$), number of fruits per cluster ($r = 0.75^{**}$), total fruit number per plant ($r = 0.36^{*}$), number of clusters per plant ($r = 0.67^{**}$) and dry matter content ($r = 0.75^{**}$). Differences in total fruit yield in both growth conditions and the different varieties could therefore be explained by the differences in height of the plant, number of fruit per cluster and number of clusters per plant. These all variables were enhanced under greenhouse than in open sun conditions. In addition, high rate of photosynthesis was observed in greenhouse than in open sun condition. The higher the rates of photosynthesis, the higher the amount of dry matter production, i.e. higher total crop photosynthesis [19]. Higher amount of production supports more number of fruits per cluster and more number of clusters per plant. Higher total fruit yield per plant in greenhouse compared yield in open field have also been reported in some previous studies [e.g. 16, 20]. In addition to increased amount of fruit yield, greenhouse condition also increased percentages of total marketable fruits per plant (Table 3). This indicates that there was fruit quality improvement in greenhouse than in open field conditions.

Fruit length, fruit diameter and fruit shape index were also significantly ($p < 0.01$, Table 4) affected by growing conditions and tomato varieties. Fruits harvested from greenhouse were longer with larger diameter and higher shape index than fruits harvested from open sun. Among varieties, Marglobe had the longest fruit with largest diameter in both growing conditions. The largest fruit shape indexes, on the other hand, were observed in Bishola, Moneymaker and Eshet (Table 4).

Total soluble solids varied among varieties grown in greenhouse. In open field, however, the variations in TSS among varieties were not significant. Variety Eshet grown in greenhouse had the highest TSS (5.5 °brix) while Moneymaker had the lowest in both growing conditions (Table 5). Regardless of the growing conditions, the TSS values observed in this study were in the range of values reported by Wahundeniya *et al*. [21] and Lekshmi and

Table 4: Fruit length (cm), fruit diameter (cm) and fruit shape index of tomato varieties grown under green house climate and open field

	Fruit length (cm)		Fruit diameter (cm)		Fruit shape index	
Varieties	Green house	Open field	Green house	Open field	Green house	Open field
Bishola	4.90[a]	4.50[ab]	5.97[a]	5.27[b]	0.82[a]	0.86[a]
Eshet	5.15[a]	5.17[a]	6.25[a]	5.82[ab]	0.82[a]	0.89[a]
Marglobe	3.74[b]	3.56[c]	6.10[a]	6.93[a]	0.62[b]	0.51[b]
Moneymaker	3.92[b]	3.94[bc]	4.75[b]	5.12[b]	0.82[a]	0.77[a]
LSD (5%)	0.3579	0.7525	0.7644	1.1868	0.1032	0.1631
CV (%)	4.04	8.73	6.62	10.24	6.65	10.73

Means followed by the same letter within the same column are not significantly different at 5% level of significance

Table 5: Total soluble solid (°Brix), titratable acidity, pH and dry matter content of tomato varieties grown under green house climate and open field

	Total soluble solids (°Brix)		Titratable acidity (% citric acid)		pH		Dry matter content	
Varieties	Green house	Open field	Green house	Open field	Green house	Open field	Green house	Open field
Bishola	4.16[c]	5.33	0.24[a]	0.21[ab]	4.31[b]	4.38[a]	12.59[c]	17.37[a]
Eshet	5.50[a]	5.33	0.15[b]	0.25[a]	4.07[b]	3.87[b]	15.94[bc]	12.00[b]
Marglobe	4.83[b]	5.00	0.28[a]	0.17[bc]	4.57[a]	4.29[a]	21.47[a]	17.56[a]
Moneymaker	4.16[c]	4.50	0.12[b]	0.13[c]	4.30[b]	4.34[a]	17.23[b]	17.66[a]
LSD (5%)	0.471	NS	0.046	0.053	0.243	0.268	4.035	3.272
CV (%)	5.05	7.20	11.42	13.87	2.59	3.18	12.01	10.14

Means followed by the same letter within the same column are not significantly different at 5% level of significance

Celine [22]. Tomato TSS is mostly composed of reducing sugar. Thus, any factor, e.g. seasonal climatic variation and horticultural practices that alters sucrose synthesis (photosynthetic activity) affects glucose and fructose accumulation in the fruits and TSS [7]. This study indicated that TSS is also variety dependent.

Titratable acidity and pH are the most commonly used acidity indicators of tomato. In this study, tomato titrable acidity (TA) and pH were also influenced by both growing conditions and differences in tomato varieties (Table 5). The highest TA and pH were observed in greenhouse than in open field. Among varieties, Marglobe had the highest value for both variables. Tittonell *et al.* [23] reported that large sized tomato fruit had higher acidity than small sized fruits. Our results also confirmed this finding and are in agreement with those reported by Meseret [5]. The lower acidity of the fruits grown in open field may be a result of the lower photosynthetic activity of the plant and lower carbohydrate accumulation in the fruits. According to Tigist *et al*. [24], genetic factor is also the major determinant tomato fruits acid content. Similar to TA, pH can easily be affected by differences in variety and maturity level of the fruit.

Tomatoes dry matter production was also affected by both varieties and growing conditions (Table 5). Dry matter content of tomato grown in greenhouse ranged from 13 to 22% while the corresponding range in open field condition was 12 to 18%. In greenhouse, variety Marglobe accumulated the highest dry matter. In open sun, maximum dry matter (18%) was accumulated by Moneymaker. Dry matter accumulation was positively and strongly correlated ($r = 0.49^{**}$) with plant photosynthetic rates. According to Tadahisa *et al.* [25], differences in fruit dry matter content might be attributed to differences in light use efficiency among varieties and the availability of suitable climatic conditions that enhances photosynthetic capacity of these varieties.

CONCLUSIONS

The study in general indicated that growing conditions and varietal differences affect yield and quality characteristics of tomato fruits. Growing tomato under greenhouse conditions improves yield via enhancing yield contributing characteristics. Tomato yield per plant in greenhouse was 54% more than the average yield per plant in open sun. Greenhouse conditions also improved tomato fruit quality. Larger fruits with higher shape index and dry matter contents were harvested from tomato plants grown under greenhouse conditions. In all these quality attributes, variety Marglobe, Moneymaker and Bishola were found as promising varieties in both growing conditions. Research is, however, needed to evaluate some other varieties and agronomical practices to further substantiate the conclusion.

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