Middle-East Journal of Scientific Research 24 (9): 2904-2908, 2016
ISSN 1990-9233
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DOI: 10.5829/idosi.mejsr.2016.24.09.23961

Growth and Physiological Responses of Different Tomato (*Solanum lycopersicum*) Varieties in Relation to Growth Conditions

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Abstract: Tomato is one of the vegetable crops with the highest production. In Ethiopia the productivity is, however, far below the average due to a number of factors limiting productivity. Among which lack of improved technologies (e.g. greenhouse) are the most important ones. This study was conducted to evaluate tomato responses to the different growing conditions and select suitable varieties for promoting tomato production in protected environment. The experiment was conducted at Jimma University College of Agriculture in both greenhouse and open field conditions. Four different varieties were used for this experiment and were arranged in RCBD in both growing conditions. The result of the study indicated that all tomato varieties grown in the greenhouse showed vigorous growth with larger leaf area, longer plant height, more number of flowers per cluster and number of flower clusters per plant. The percentage of fruit set per plant was also greater in greenhouse than in open field. Similar to growth variables, physiological responses of each tomato variety were also convincing that greenhouse conditions were much better than conditions in open field. Among varieties, variety Marglobe inside greenhouse and Bishola under open field grew vigorously. The result generally indicated that Margolobe variety is suitable for protected cultivation while Bishola is promising for open field condition.

Key words: Greenhouse · Open field · Stomatal conductance · Marglobe · Bishola

INTRODUCTION

Tomato is one of the vegetables with the highest production in the world. It is an important cash-generating vegetable crop to small-scale growers and provides opportunities for employment in the production and processing plants [1]. Its production is more attractive than any other vegetable crops for its multiple harvests, which results in high profit per unit area of land [2]. In Ethiopia the productivity is, however, far below the average [3]. The productivity under farmers' condition was 9 t/ha, where as yield up to 40 t/ha can be recorded on research plots [4]. There are a number of factors which limit tomato productivity and management systems. Among which adverse environmental factors and lack of improved technologies (e.g. greenhouse) are the most important ones [5].

The market values of tomatoes are determined by fruit quality and productivity [6]. Field grown fruits, however, can be coated with soil or dust particles and affect quality and shelf life [7]. Keeping the fruits free of disease and insect pests is also a significant challenge. In different parts of the world, various plastic culture systems are in common use for a year round fresh tomato production [8, 9, 10]. However, growing tomato crop in protected environments is not yet established in the country.

In Ethiopia, tomatoes are widely produced by small farmers and commercial growers [11]. Several tomato cultivars have also been released and recommended by Melkassa Agricultural Research Center. But, varieties that cope up with protected environmental conditions are not yet identified. This study was, therefore, initiated to fill this gap through evaluating performances of different tomato varieties at both open and greenhouse conditions.

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Table 1: List of varieties and their description

Variety name	Year of release	Growing altitude (m asl)	Growth Habit	MaturityDays (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: [15].

MATERIALS AND METHODS

The experiment was conducted at Jimma University College of Agriculture and Veterinary Medicine, newly 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 [12].

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 [13]. Data on growth and physiological variables were collected from the middle twelve plants and subjected to ANOVA using SAS vr.9.2 (SAS Institute Inc., 2008). Mean separation was carried out using LSD (Least Significant Difference) test at 5% level of significance [14].

RESULTS AND DISCUSSIONS

Growth Variables: The result of the study indicated that all tomatoes grown in the green house showed vigorous growth with larger leaf area than in open sun condition. Within each growth conditions, there were also highly significant differences ($P<0.01$) in plant height and leaf area between the different tomato varieties (Table 2). Inside the greenhouse, variety Moneymaker was grown to the height of 265.3 cm while under open field condition this variety was grown to a maximum height of 102.6 cm. Under the two treatment conditions, variety Bishola was observed to have the shortest plant height (Table 2). However, the height of this variety under greenhouse condition was statistically at par with the maximum height (Moneymaker, 102.6 cm) observed in the open field condition.

In greenhouse leaf area per plant ranged from 279 to 503 cm^2. The corresponding value in open sun was, however, ranged from 96 to 230.4 cm^2. Within the varieties, variety Marglobe grown in greenhouse had the largest (503 cm^2) leaf area while in open sun leaves of variety Moneymaker were grown to a leaf area of 230.4 cm^2.

Greenhouse provides suitable microclimates for crop growth. This favorable microclimatic conditions prevailed inside greenhouse enhances plant metabolic activities like photosynthesis and promote plant growth and development [16]. Similar findings were also reported for other tomato varieties [5, 17] and for cucumber [18]. These authors reported that crops growing in greenhouse are vigor with larger leaf area and better performance than corresponding crops growing in open field. These differences are attributed to the availability of optimum climatic condition in greenhouse compared to conditions in open field. Such suitable climatic conditions promote cell division and cell elongation which eventually led to larger leaf area and taller plant height. Crops need sufficiently large leaf area per unit land area (LAI) to intercept more light. For optimal light interception a leaf area index of about 3 to 4 is needed [19].

Number of flowers per cluster was less likely affected by the growing conditions. The differences were, however, clearly observed between varieties. In both greenhouse and open sun, an average of 9.3 flowers per cluster were observed on variety Moneymaker while lower number of flowers per cluster 5.9 and 5.3 were, respectively observed on variety Eshet and Bishola.

Unlike the number of flowers per cluster, number of flower clusters per plant was affected by the growing conditions (Table 3). In greenhouse flower clusters per plant ranged from 7.3 to 21.0 while the corresponding range in open sun was 6.7 to 14.5. Under both growing conditions, tomato variety Marglobe developed the highest flower clusters per plant while Bishola developed

Table 2: Plant height and leaf area per plant of tomato varieties grown under greenhouse and open field

	Plant height (cm)		Leaf area (cm^2)	
Varieties	Green house	Open field	Green house	Open field
Bishola	103.06^{c}	61.94^{c}	379.06^{ab}	95.65^{b}
Eshet	223.84^{ab}	90.22^{ab}	436.22^{a}	127.28^{b}
Marglobe	206.92^{b}	75.48^{bc}	502.82^{a}	124.96^{b}
Money maker	265.28^{a}	102.6^{a}	279.20^{b}	230.37^{a}
LSD (5%)	39.562	16.210	125.030	47.536
CV (%)	9.91	9.82	15.67	16.56

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

Table 3: Number of flowers per cluster, number of flower clusters per plant and fruit set percentage of tomato varieties grown under greenhouse and open field

	Number of flowers per cluster		Number of flower clusters per plant		Fruit set percentage	
Varieties	Green house	Open field	Green house	Open field	Green house	Open field
Bishola	5.53^{c}	9.15^{a}	7.33^{c}	6.73^{b}	85.90^{ab}	63.01^{b}
Eshet	6.10^{bc}	5.89^{c}	14.66^{b}	10.66^{ab}	97.73^{a}	77.24^{ab}
Marglobe	9.51^{a}	9.10^{ab}	21.00^{a}	9.80^{ab}	72.07^{c}	60.75^{b}
Money maker	7.93^{ab}	6.48^{bc}	14.91^{b}	14.53^{a}	82.00^{bc}	85.64^{a}
LSD (5%)	2.388	3.180	5.867	4.890	13.272	16.835
CV (%)	16.44	20.78	18.94	20.96	7.86	11.75

the lowest number in both greenhouse and open sun growing conditions. The increase in number of flower clusters per plant under greenhouse compared to numbers in open sun was also reported in some previous studies e.g. [20, 21, 22].

Number of flower clusters per plant is directly correlated with plant height. In this study we observed tallest plant height under greenhouse compared to plant height in open sun. The taller the plant height and the optimum the temperature in the greenhouse, the more the number of flower cluster per plant. Number of flower clusters per plant directly influence fruit yield and is used as the major criteria for selecting varieties for their yield and fruit size.

Similar to number of flower clusters per plant, percentage of fruit set per plant was also significantly affected by the growing conditions and also by the differences in tomato varieties (Table 3). In greenhouse about 98% of fruit was set while in open sun the maximum was only 87%. Among varieties, variety Eshet (98%) and Bishola (86%) that were grown in greenhouse had the highest fruit set percentage. In open sun variety, Moneymaker had the highest fruit set percentage (86%). Fruit set percentage on tomato varieties is one of the important parameters for tomato production, which determines the sensitivity and tolerance of a variety to a particular temperature and environment. The highest fruit set percentage observed under greenhouse might be due to less interference of adverse climatic conditions like rainfall and wind velocity during crop growth and development.

Physiological Variables: The result of the study showed that tomatoes grown under both conditions showed significant differences in their chlorophyll florescence, photosynthetic rates, stomatal conductance and leaf transpiration rate (table 4). Chlorophyll fluorescence is the efficiency of plant leaf to convert absorbed light to chemical energy and the value indicates the status of plant stress [23]. Under greenhouse condition, variety Marglobe had maximum chlorophyll fluorescence value (0.9 $\mu mol\ m^{-2}s^{-1}$) compared to all other varieties. In open, sun the maximum value (0.75 $\mu mol\ m^{-2}s^{-1}$) for this variable was observed in variety Bishola. The lower value under open sun compared to greenhouse condition showed that tomato plants grown in open sun were relatively stressed due to high light intensity and temperature. This reduces the ability of the plants to undertake the normal physiological processes. Under normal physiological conditions, plants convert about 80 – 90% of the absorbed light in to chemical energy. The values decrease with increase in plant stress indicating imbalance between light absorption and light utilization [24]. These findings are in line with results reported in [25].

Table 4: Chlorophyll fluorescence, photosynthetic rate, stomata conductance and transpiration rate of tomato varieties grown under green house climate and open field

	Chlorophyll fluorescence		Photosynthetic rate		Stomata conductance		Transpiration rate	
Varieties	Green house	Open field	Green house	Open field	Green house	Open field	Green house	Open field
Bishola	0.80[b]	0.75[a]	8.34[b]	9.77[a]	0.24[b]	0.20[b]	1.94[b]	1.61[ab]
Eshet	0.81[b]	0.67[b]	7.37[b]	6.29[b]	0.26[b]	0.20[b]	1.96[b]	1.44[b]
Marglobe	0.90[a]	0.64[bc]	10.36[a]	6.58[b]	0.46[a]	0.50[a]	2.06[b]	1.96[a]
Moneymaker	0.81[b]	0.59[c]	7.29[b]	6.14[b]	0.26[b]	0.24[b]	2.41[a]	1.36[b]
LSD (5%)	0.0381	0.0642	0.9875	0.8916	0.0823	0.1269	0.2655	0.1905
CV (%)	2.28	4.80	5.92	6.19	13.21	21.79	6.32	5.97

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

Both photosynthetic rate and stomatal conductance also differed *($p<0.001$)* among tomato varieties in both growth conditions (Table 5). Inside greenhouse, variety Marglobe had highest photosynthetic rate (10.36 μ mol CO_2 m^{-2} s^{-1}) while variety Bishola had the highest value (9.77 μ mol CO_2 m^{-2} s^{-1}) in open sun. In both growth conditions, the highest stomatal conductance values were observed in variety Marglobe. Leaf photosynthetic rate is determined by the amount of photosynthetic protein per leaf area and CO_2 conductance in stomata. Photosynthetic rate increases with increase in plants' ability to harvest light energy and stomatal conductance for CO_2 [26]. Stomatal opening affects photosynthesis by regulating intercellular CO_2 concentration and thereby the bio-chemical processes in chloroplasts [27]. In this study, it was observed that both growth conditions and the genetic characteristics of the varieties affected light absorption and stomatal movement and hence photosynthetic rate.

CONCLUSION

In this study varieties differed significantly in plant height (cm), leaf area (cm^2), fruit set percentage, number of flower clusters per plant, number of flowers per cluster and in their physiological characteristics. Tomatoes plants grown under greenhouse condition showed vigorous growth compared to tomatoes grown in open sun. Among varieties, variety Marglobe inside greenhouse and Bishola under open field showed promising responses and vigorous growth. The result generally indicated that Margolobe is the variety suitable for protected cultivation while Bishola performs best under open field condition. This study is, however, the first of its kind identifying varieties for protected cultivation system in the study area. It is therefore advisable to further evaluate the yielding ability of the variety and its fruit quality in such growing conditions. Establishment cost of protected cultivation is probably high for resource poor farmers. However, low cost, locally available materials like bamboo (wood) and transparent polyethylene covers can be used to establish sound protected production system in the area.

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