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Yield and Pest Performance of High-Temperature Tolerant Tomato (*Lycopersicon esculentum*) Lines for Year-Round Tomato Production in Bangladesh

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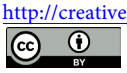

Abstract

The study was conducted at Olericulture Division, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh during summer season of 2021 to see the performances of yield and yield-related components of twelve heat tolerant tomato hybrids. Significant variation was expressed for days to first harvest (101.0 - 108.0 days), while maximum number of fruits per plant was calculated in F_1 2101 and F_1 2201 (9.5), followed by F_1 203, F_1 2001, F_1 2303, F_1 2401 (9.0). The highest single fruit weight was estimated in F_1 2501 (195.5 g), followed by F_1 2101 (119.0 g), F_1 2201 (113.8 g), while the range was 33.1 - 195.5 g. The range of fruit yield was 7.9 - 38.7 t/ha, while higher-yielding hybrids were viz., F_1 203 (27.7 t/ha), F_1 2101 (35.5 t/ha), F_1 2201 (33.9 t/ha) and F_1 2501 (28.7 t/ha). Maximum TSS was produced by F_1 2501 (5.9%), followed by BARI Hybrid Tomato-8 (5.1%), F_1 1101, F_1 1903 (5.0%), with a range of 4.0% - 5.9%, while TYLCV infection and leaf sucking pest infestation varied from 0.0% - 10.0% and 3.3% - 16.7%, respectively. Thus, based on the performances of different yield and yield contributing traits, the hybrids, viz., F_1 2101, F_1 2201, F_1 2501 may be selected to develop heat tolerant tomato hybrid varieties for the farmers of sub-tropical regions.

Keywords

Lycopersicon esculentum, Tomato Hybrids, Heterosis, Sub-Tropical

1. Introduction

Tomatoes (*Lycopersicon esculentum*) are an extremely popular, economically

important, and widely grown vegetable crop in Bangladesh as well as around the world. It is rich in a plethora of natural antioxidants and bioactive compounds. The regular ingestion of an adequate amount of fresh tomatoes or processed tomato products has been inversely correlated with the development of widespread human diseases [1] [2] [3] and with an increase in plasma lipid peroxidation levels [4] [5]. This protective effect has been attributed primarily to the carotenoid constituents of the fruits, particularly lycopene and beta-carotene, which act as antioxidants in detoxifying free radicals [2] [6] [7]. In addition to its large production values, the tomato is an important source of antioxidant intake.

Commercial exploitation of hybrid vigour in tomatoes has gained greater importance on account of several advantages of hybrids over pure line varieties, including resistance or tolerance to biotic and abiotic stresses. Tomatoes have achieved the spectacular status of functional food because of their rich nutritional composition and widespread consumption. Tomato being a highly self-pollinated species, the scope for exploitation of hybrid vigour depends on the direction and magnitude of heterosis, and the ease with which hybrid seeds can be produced. The fruit setting of most tomato cultivars under high night and day temperatures have been a limiting factor for tomato production in tropical and subtropical areas of the world. Although tomato plants can be grown under a wide range of climatic conditions, they are extremely sensitive to hot and wet conditions, the type of weather that prevails in the summer season in Bangladesh [8]. Fruit setting in tomatoes is reportedly interrupted at temperatures above 26/20˚C day/night, respectively, and is often completely arrested above 38/27˚C day/night. [9] [10] [11]. Several efforts have been made so far to overcome the high temperature barrier, which ultimately led to the development of several heat-tolerant tomato varieties in Bangladesh. Since consumers and producers' preferences are diverse, there is a great demand for new, good-quality, heat-tolerant hybrid varieties of tomatoes.

Hence, the identification of high-yielding and stable varieties and the development of F_1 hybrids will help farmers adopt the variety/hybrid for successful commercial cultivation of tomatoes. Heterosis in tomatoes was first observed by [12] for higher yield and a greater number of fruits. The reproductive biology and production of an appreciable quantity of seeds per fruit provide ample opportunity for the manifestation of heterosis in tomatoes [13].

With these points in view, heterosis and combining ability studies are prerequisites in any plant breeding program, which provides the desired information regarding varietal improvement or exploiting heterosis for commercial purposes [14]. Bangladesh Agricultural Research Institute (BARI) has developed a good number of summer tomato varieties. Since farmers' and consumers' preferences have diverged, more summer tomato varieties need to be developed. As part of this activity, BARI has developed some heat-tolerant tomato hybrids with the help of Asian Food and Agriculture Cooperation Initiative (AFACI) and World Vegetable Center (WVC). Now, these hybrids need to be evaluated during the

summer season to see the performances of vegetative, yield, and quality traits of tomato hybrids in Bangladesh.

2. Materials and Methods

2.1. Experimental Site

The experiment was conducted at the Olericulture Division of the Horticulture Research Centre, Bangladesh Agricultural Research Institute, Bangladesh. The experimental field was in a sub-tropical region of 23.9920˚N latitude and 90.4125˚E longitude, having an elevation of 8.2 m from sea level.

2.2. Treatments and Plant Materials

Twelve tomato crosses viz., F_1 203, F_1 1101, F_1 1501, F_1 1903, F_1 2001, F_1 2101, F_1 2201, F_1 2203, F_1 2301, F_1 2303, F_1 2401, F_1 2501 were incorporated in this study. The seeds of these crosses and parents were sown on the polypot on 10 May, 2021. BARI Hybrid Tomato-8 was used as check variety. Thirty-day days old seedlings were transplanted in the main field on 09 June, 2021.

2.3. Land Preparation and Fertilization

The experiment was laid out in a Randomized Complete Block design with three replications. The unit plot size was 5.0 × 1.0 m maintaining 60 × 50 cm spacing and 0.5 m drain. The experimental area was enriched with organic manure, Nitrogen, Phosphorus, Potassium, Sulphur, Zinc and Boron @ 3000, 250, 90, 125, 20, 3 and 2 kg/ha, correspondingly. One third of the organic manure, 50% of Phosphorus and full of Sulphur, Zinc and Boron were incorporated for the period of last land-dwelling preparation. Rest of organic fertilizer and Phosphorus and 1/3 of Potassium were applied as basal in pit. Entire quantity of Nitrogen and rest of Potassium were applied in three equal portions beginning 20 days after transplanting. The remaining three portions were fertilized at 20, 40, and 60 days after transplanting. The intercultural operations (weeding, irrigation, etc.) were done as and when necessary.

2.4. Air Temperatures and Relative Humidity of the Experimental Area

Under protected conditions, temperatures can be monitored and managed, and better plant growth could be expected. The protected net house condition influenced the air temperature and RH. Data for the temperatures and RH were measured at 12 pm daily during the experimental period. The average minimum and maximum temperatures varied between 25.8˚C (January, 2021) to 36.8˚C (July, 2021), while relative humidity varied between 62.1% to 81.5% in day time (**Figure 1**).

2.5. Data Collection and Statistical Analysis

Data on days to first flowing, days to 50% flowing, days to first harvest, days to

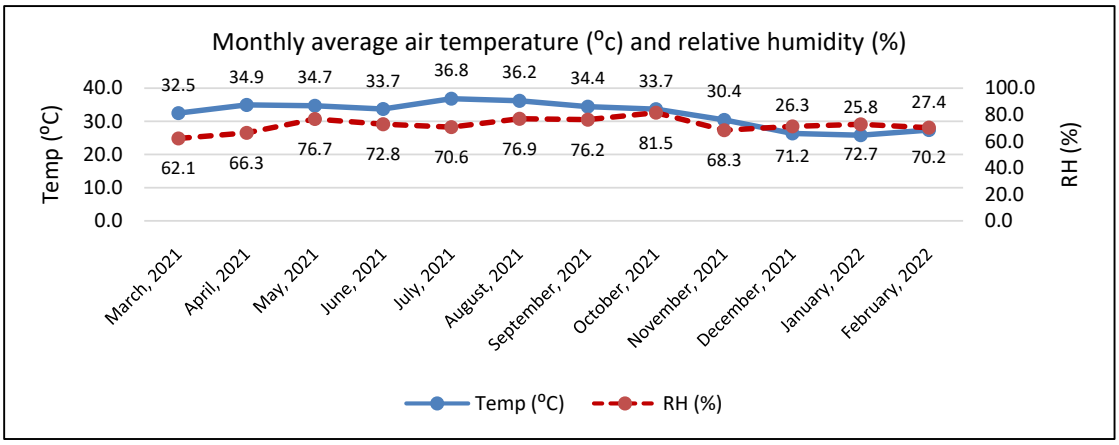

Figure 1. Monthly average air temperature (˚C) and relative humidity (%) at 12 hrs during March 2021 to Feb 2022 at Gazipur, Bangladesh.

fruit maturity, no. of clusters per plant, no. of flowers per cluster, no. of fruits/cluster, no. of fruits/ plant, single fruit wt. (g), fruit yield/plant (kg), fruit length (cm), fruit diameter (cm), pericarp thickness (cm), TSS (%), no. of locules, plant height at last harvest (cm), TYLCV (%), and leaf sucking pest (%) were recorded from three randomly selected plants per plot. The information on different characters was statistically analyzed. The collected data were statistically analyzed, and treatment means were compared using the Duncun Multiple Range Test (DMRT).

3. Results and Discussion

There was significant variation observed among the 12 hybrids of tomato during the summer season of 2021. A significant difference among hybrids was observed for all the characters studied (**Tables 1-3**). Earliness is important character to get premium prices in a market. Significant variation was expressed for days to first flowering (62.1 - 68.1 days), days to 50% flowing (67.1 - 73.1 days), days to first harvest (101.0 - 108.0 days), days to fruit maturity (32.1 - 36.1 days) (**Table 1**). Early flowering in hybrids has also been reported by [15] [16] [17]. The range of the number of cluster per plant and the number of flower per cluster were 6.0 - 28.8 and 3.1 - 8.3, respectively.

Significant variations were observed for the number of fruits per cluster, which varied from 2.2 - 4.6, while the maximum was produced by F_1 1903 (4.6), followed by F_1 2301 (3.9), and F_1 2201 (3.2) (**Table 2**). The number of fruits per plant is one of the most important traits that is directly related to increased fruit yield per plant. Significant maximum number of fruits per plant was calculated in F_1 2101 and F_1 2201 (9.5), followed by F_1 203, F1 2001, F_1 2303, F_1 2401 (9.0), while the minimum was from F_1 2301, F1 2501 (6.0) (**Table 2**). The variation in the number of fruits per plant may be due to genetic differences among the crosses since they were grown under the same environmental conditions. The finding is in agreement with [18] [19]. Single fruit weight has a direct contribution to

yield. F_1 2501 had the highest single fruit weight (195.5 g), followed by F_1 2101 (119.0 g), F_1 2201 (113.8 g), and F_1 203 (92.8 g), with a range of 33.1 - 195.5 g (**Table 2**). [8] also found the range of individual fruit weight to be from 5.25 g to 43.38 g among 25 heat tolerant hybrids, which supports the findings of the present study. The studies corroborate the findings of [1] [20] [21]. The ultimate goal of any breeding program is to achieve a higher marketable yield per unit of area. Fruit-set in tomatoes influences yield through effects on both fruit number and fruit size [22]. Fruit yield ranged from 7.9 to 38.7 t/ha, with the highest yielding hybrids being F_1 203 (27.7 t/ha), F_1 2001 (25.8 t/ha), F_1 2101 (35.5 t/ha), F_1 2201 (33.9 t/ha), F_1 2303 (25.1 t/ha), and F_1 2501 (28.7 t/ha). The studies corroborate the findings of [23] [24]. Higher fruit yield per plant in some hybrids may be due to the production of a greater number of fruits with a greater single fruit weight as compared to their respective set of parents. The development of fruit size depends on a number of factors such as the leaf-fruit ratio, genetic and climatic factors, position in the plant and the branch, plant age, number of seeds, and water and nutrient supply [25]. The range for fruit length and fruit diameter was 3.8 - 6.4 cm and 3.7 - 7.2 cm, respectively.

Table 1. Performance of yield and yield contributing characters of heat tolerant tomato hybrids.

Hybrids	Days to first flowering	Days to 50% flowering	Days to first harvest	Days to fruit maturity	No. of cluster per plant	No. of flower per cluster
F_1 203	66.1	69.1	101.0	32.1	24.0	5.4
F_1 1101	67.1	71.1	107.0	36.1	21.0	4.7
F_1 1501	68.1	72.1	107.0	35.1	25.0	4.9
F_1 1903	65.1	73.1	108.0	35.1	16.4	4.5
F_1 2001	64.1	69.1	102.0	33.1	23.7	5.3
F_1 2101	62.1	67.1	101.0	34.1	24.8	6.5
F_1 2201	67.1	70.1	103.0	33.1	18.8	6.3
F_1 2301	67.1	72.1	106.0	34.1	19.2	6.2
F_1 2303	65.1	69.1	102.0	33.1	28.8	5.5
F_1 2401	65.1	69.1	102.0	33.1	16.8	8.3
F_1 2501	67.1	70.1	103.0	33.1	6.0	3.1
BARI Hybrid Tomato-8	64.1	70.1	104.0	34.1	19.6	6.1
St. Dev.	1.73	1.68	2.52	1.14	5.85	1.28
St. Error	0.50	0.48	0.73	0.33	1.69	0.37
CV (%)	0.03	0.02	0.02	0.03	0.29	0.23

Table 2. Performance of yield and yield contributing characters of heat tolerant tomato hybrids.

Hybrids	No. of fruits/ cluster	No .of fruits/ plant	Single Fruit wt. (g)	Fruit yield (t/ha)	Fruit length (cm)	Fruit diameter (cm)
F_1 203	2.9	9.0	92.8	27.7	4.8	4.5
F_1 1101	2.6	7.0	33.1	7.9	3.8	3.7
F_1 1501	2.4	7.0	71.1	16.6	4.5	5.2
F_1 1903	4.6	7.0	58.5	13.7	4.1	4.7
F_1 2001	2.7	9.0	86.5	25.8	4.4	5.3
F_1 2101	2.8	9.5	119.0	35.5	5.2	5.6
F_1 2201	3.2	9.5	113.8	33.9	5.3	6.0
F_1 2301	3.9	6.0	86.5	17.3	5.1	4.8
F_1 2303	2.4	9.0	83.8	25.1	4.3	5.1
F_1 2401	3.8	9.0	88.9	26.5	5.2	4.2
F_1 2501	2.2	6.0	195.5	38.7	6.4	7.2
BARI Hybrid Tomato-8	3.2	7.0	65.5	15.3	4.3	4.1
St Dev	0.72	1.36	40.20	9.58	0.70	0.95
St Error	0.21	0.39	11.61	2.77	0.20	0.27
CV (%)	0.24	0.17	0.44	0.40	0.15	0.19

Table 3. Performance of yield and yield contributing characters of heat tolerant tomato hybrids.

Hybrids	Pericarp thickness (mm)	No. of locules/ fruit	TSS (%)	Plant height at last harvest (cm)	TYLCV (%)	Leaf sucking pests (%)
F_1 203	2.0	4.0	4.3	123.1	3.3	10.0
F_1 1101	2.0	3.0	5.0	129.0	6.7	6.7
F_1 1501	2.0	5.3	4.0	125.2	10.0	10.0
F_1 1903	4.0	3.0	5.0	128.9	6.7	10.0
F_1 2001	2.0	3.0	4.0	125.1	6.7	10.0
F_1 2101	2.0	5.5	4.0	119.7	0.0	10.0
F_1 2201	2.0	5.6	4.0	120.0	0.0	3.3
F_1 2301	2.0	4.0	4.8	119.7	10.0	10.0
F_1 2303	2.1	5.0	4.0	126.7	3.3	3.3
F_1 2401	3.0	3.0	4.4	123.3	6.7	3.3
F_1 2501	4.0	5.0	5.9	121.8	3.3	10.0
BARI Hybrid Tomato-8	4.0	3.7	5.1	160.7	16.7	16.7
St Dev	0.89	1.05	0.62	11.13	4.69	3.90
St Error	0.26	0.30	0.18	3.21	1.35	1.13
CV (%)	0.35	0.25	0.14	0.09	0.77	0.45

Pericarp thickness is an important factor in maintaining tomato shelf life and quality. The potential hybrids must have produced thicker pericarps than the parents involved in the hybrids. In this study, the thickness range was 2.0 - 4.0 mm. [26] agreed on the outcome of this study. The number of locules in a tomato affects the shape and size of the fruit. The locules are formed directly from the carpels in the flower. Even though having fewer locules in a fruit is desirable, the hybrids that produce fewer locules are F_1 1101, F_1 1903, F_1 2001, and F_1 2401 (3.0). In tomato, [21] supported the findings. Total soluble solids (TSS) content is one of the most important quality parameters for the processing industry. It represents the sum total of all fruit components other than water and volatile compounds. Maximum TSS was produced by F_1 2501 (5.9%), followed by BARI Hybrid Tomato-8 (5.1%), F_1 1101, F_1 1903 (5.0%), while the range was 4.0% - 5.9% (**Table 3**). This confirms the findings of [27] [28]. Higher plant height is considered desirable because it leads to a greater number of branches and ultimately results in increased productivity. The range of height was 119.7 cm (F_1 2101) to 160.7 cm (BARI Hybrid Tomato-8). Pest and disease infestation were the most important parameters to be followed during crop production as well as to select good quality hybrids, while the TYLCV infection and leaf sucking pest infestation varied from 0.0% - 10.0% and 3.3% - 16.7%, respectively (**Table 3**).

4. Conclusion

There was significant variation observed among the twelve tomato hybrids. The ultimate goal of a plant breeder and a basic requirement of any breeding program is to increase yield, which correlates directly or indirectly with other plant traits and biotic and abiotic stress. Days to first flowering (62.1 - 68.1 days), days to 50% flow (67.1 - 73.1 days), days to first harvest (101.0 - 108.0 days), and days to fruit maturity (32.1 - 36.1 days) showed significant variation, while the maximum number of fruits per plant was calculated in F_1 2101 and F_1 2201 (9.5), followed by F_1 203, F_1 2001, F_1 2303, and F_1 2401 (9.0). The higher single fruit weight was estimated in F_1 2501 (195.5 g), F_1 2101 (119.0 g), F_1 2201 (113.8 g), F_1 203 (92.8 g). The range of fruit yield was 7.9 - 38.7 t/ha, while higher-yielding hybrids were viz., F_1 203 (27.7 t/ha), F_1 2001 (25.8 t/ha), F_1 2101 (35.5 t/ha), F_1 2201 (33.9 t/ha), F_1 2303 (25.1 t/ha) and F_1 2501 (28.7 t/ha). Higher TSS was produced by F_1 2501 (5.9%), BARI Hybrid Tomato-8 (5.1%), F_1 1101, F_1 1903 (5.0%), with a range of 4.0% - 5.9%, while TYLCV infection and leaf sucking pest infestation varied from 0.0% - 10.0% and 3.3% - 16.7%, respectively. Thus, it is evident from the study that based on the performances of different yield and yield contributing traits, the hybrids, viz., F_1 2101, F_1 2201, F_1 2501 may be selected to develop heat tolerant tomato hybrid varieties for sub-tropical Region.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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