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Performance Evaluation of Tomato (*Solanum Lycopersicum* L.) Hybrids for Increased Productivity under Polyhouse Conditions in Temperate Areas

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Abstract: Tomato (*Solanum lycopersicum* L.) is one of the leading vegetable crops in the world. In order to harness boom in tomato productivity, tomato hybrids are evaluated under varied agro-climatic conditions especially protected conditions. In the present study, morphological and biochemical properties of fourteen fresh tomato hybrids were analyzed under polyhouse in mid hill condition of Uttarakhand, India. The experiment was conducted during s rainy eason of 2012-2013 in randomized block design with three replications and fourteen treatments (each hybrid representing one treatment). The results showed that the tomato hybrid Himraja could perform outstandingly well for various morphological and quality characters viz., plant height (315.00 cm), percent fruit set (84.09 %), higher number of marketable fruits per plant (58.53), maximum marketable fruit yield per hectare (1080.00 q) and high TSS (7.98 ºBrix) as compared to all other hybrids. Besides, it also proved the best with respect to disease resistance and profitability.

Keywords: Polyhosue, Tomato hybrids, Growth, Yield and Quality

1. Introduction

Tomato (*Solanum lycopersicum* L.; 2n=2x=24) is one of the most important members of nightshade family that are widely grown in many countries across the globe. It is originated and domesticated in Andean region of South America and in Mexico [1]. In earlier times, tomato was considered as poisonous and grown as an ornamental plant. Today, it is the second largest cultivated vegetable crop in the world after potato [2]. Its cultivation has spread throughout the world occupying an area of 4.62 million ha with an annual production of 128.00 million ton [3]. Tomato is mainly grown in China, India, USA, Italy, Turkey and Egypt. In India, it occupies an area of 0.63 million ha with an annual production of 12.43 million tones and productivity of 19.60 mt/ha.

In Uttarakhand, tomato is also a very important off-season vegetable crop that fetches great remunerations to the farmers. It may be cultivated in open as well as in protected conditions. But, its cultivation under field conditions is not very profitable because of unfavourable weather. Thus, there is a huge scope of tomato cultivation under polyhouse conditions especially in mid hill regions of Uttarakhand. There are number of hybrids varieties which can be evaluated for their yield potential for polyhouse cultivation in order to harness boom in tomato productivity. The present investigation was undertaken to study the performance of different tomato hybrids in terms of growth, yield and quality inside polyhouse under mid hill condition of Uttarakhand.

2. Material and Methods

The research was conducted at Vegetable Research Block, Department of Vegetable Science, College of Forestry and Hill Agriculture, G.B. Pant University of Agriculture and Technology, Hill Campus Ranichauri, Tehri Garhwal, Uttarakahnd, India during *summer-rainy* season of 2011-2012. Fourteen tomato hybrids including standard check namely Manisha, Heemsohna, Lakshmi, Rupali, Snehalata, Apoorva, Hill Sona, Raja, No. 7711, Lucky, Jaya (AT-99), PS-61, Himraja and Calyx-111 were included in the experiment. The experiment was laid out in Randomized Complete Block Design (RBD) with three replications under polyhouse.

2.1. Raising of Nursery

Raised nursery beds were first prepared and drenched with Captan (0.01%) before sowing the seeds in nursery beds. Seeds of fourteen tomato hybrids including standard check “Heemsohna” and “Manisha” were sown in nursery beds and then the nursery beds were watered as per requirement. Hand weeding was done at 20 and 30 days after sowing. One month old seedlings were transplanted in the polyhouse. Observation regarding days taken to first flowering, number of flower clusters per plant, fruit set percentage, plant height, number of marketable fruits per

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plant, marketable fruit weight, fruit length, fruit diameter, fruit girth, pericarp thickness, number of locules per fruit, marketable fruit yield per hectare, ascorbic acid, TSS, pH, titratable acidity and disease incidence were recorded from five randomly selected plants in each replication for each hybrid. All the agriculture operations were followed as per recommended package of practices. The fully ripe, firm and uniform tomatoes were picked up for quality analysis. The economics of tomato production under polyhouse conditions was computed as per the present market price of the produce and inputs used in the study.

3. Results and Discussion

3.1. Days Taken to First Flowering

The data were analyzed statistically, revealed that the days taken to first flowering by tomato hybrids under greenhouse condition differed significantly (Table 1). The mean number of days from transplanting to first flower initiation varied from 23.16 to 44.00. Among the different hybrids under study, the hybrid Lakshmi (23.16 days) and Apoorva (28.50 days) were earliest and statistically significant as compared to standard check Heemsohna (32.33 days) and Manisha (39.66 days). On the other hand, hybrids PS-61 and Calyx-111 being statistically similar were late in flower initiation which took number of days ranging between 32.33 to 39.66. The hybrids Snehalata, Hill Sona, Heemsohna and Himraja were statistically at par for this character.

Earliness is highly desirable attribute in all the vegetables in the sense that the prevailing price in the market invariably higher early in the season. It is also considered to be economically important trait and therefore, assumes significance in crop improvement programmes since the early flowering hybrids and varieties with high yield are usually sought for the commercial cultivation. This implied that hybrids possessed inherent differences in the duration of flowering. The flowering habit of any cultivar is influenced by the genotype itself and environmental factor under specific growing region. In general, the number of days for flowering was more in determinate types as compared to the determinate types.The numbers of flowering days of different cultivars have been reported to be ranged from 25.00 to 30.25 days after transplanting of the tomato crop by Amarananjundeshwara, *et al.* [4].

3.2. Number of Flower Clusters per Plant

The highly significant differences were found for number of flower clusters per plant in hybrids (Table 1). The mean value for this trait ranged from 6.00 to 8.33. The maximum number of flower clusters (8.33) was produced by Himraja, whereas the minimum number of flower clusters (6.00) was produced by Snehalata, which was statistically at par with the standard check Manisha (6.50). The maximum number of flower clusters per plant has contributed towards higher yield and influenced by genetic makeup of varieties/hybrids. These findings are in close agreement to that of Wahundeniya, *et al.* [5]**.**

3.3. Fruit Set Percentage

The fruit set percent was significantly affected by the tomato hybrids. It is evident from Table 1 that the range of fruit set percentage was 50.65 to 84.09 %. Fruit set percent on tomato hybrids is one of the important parameters for summer and rainy season tomato production, which determines the resistance and tolerance of a hybrid to a particular temperature and environment. The maximum fruit set (84.09 %) was observed in the hybrid Himraja which was significantly higher than all the other hybrids evaluated in the present study. HybridPS-61 had the lowest fruit set percentage (50.65 %). The perusal of results exhibited that the fruit set percentage was directly related to the fruit yield. Higher fruit set is directly correlated with more fruit yield. Similar findingwere also reported by Pandey, *et al.* [6].

3.4. Plant Height

The significant differences were found for plant height among hybrids at maturity stage because of genetic makeup of hybrids. The mean value for this trait ranged from 106.00 to 315.00 cm (Table 1). Among all the tomato hybrids, Himraja recorded maximum plant height of 315.00 cm followed by Lakshmi (211.66 cm) and Calyx-111 (118.73 cm), which were found statistically significant as compared to standard check Heemsohna (113.33 cm) and Manisha (113.73 cm). The hybrid No. 7711 with mean plant height of 106.00 cm was dwarfest among all the hybrids. Plant height is a good index of plant vigour that may contribute in higher yields. The presence of variation in plant height is the result of inherent genetic capacity of hybrids. It confirms to the findings of Hazarika and Phookan [7].

3.5. Number of Marketable Fruits per Plant

The number of marketable fruits per plant was significantly different among tomato hybrids. The mean value for this character ranged from 6.11 to 58.53 (Table 2). The maximum number of marketable fruits per plant (58.53) was observed in hybrid Himraja followed by Lakshmi (30.57) and Apoorva (24.00), which were statistically significant as compared to standard hybrids Heemsohna (8.00) and Manisha (8.41). This might be due to the more number of flowers and high value of fruit set percent because of vigorous and healthy plants. The minimum number of marketable fruits per plant was observed in hybrid PS-61 (6.11) followed by Lucky (6.47) which were statistically at par with each other. Similar results were also obtained by Rodriguez, *et al.* [8].

Table-1. Plant growth characters of different tomato hybrids under polyhouse condition

Hybrids	Days to 1st flowering	No. of flower clusters per plant	Fruit set (%)	Plant height (cm)
Lakshmi	23.16	7.83	80.50	211.66
Rupali	34.33	6.50	64.80	113.00
Snehalata	33.33	6.00	63.90	108.16
Apoorva	28.50	7.00	76.60	109.00
Hill Sona	33.16	6.83	65.93	109.73
Raja	33.66	6.83	60.39	114.73
7711	32.50	7.33	70.90	106.00
Lucky	35.83	7.00	59.60	113.73
Jaya (AT-99)	34.50	6.66	56.52	113.66
PS-61	44.00	6.66	50.65	112.73
Himraja	32.33	8.33	84.09	315.00
Calyx-111	41.66	7.33	66.30	118.73
Heemsohna (C)	32.33	7.16	58.91	113.33
Manisha (C)	39.66	6.50	65.38	113.73
CD at 5%	**2.80**	**0.90**	**2.26**	**5.49**
CV %	**4.89**	**7.67**	**2.03**	**2.44**

3.6. Marketable Fruit Weight

The weight of marketable fruits ranged from 40.770 to 71.010 g (Table 2). Among the hybrids, Rupali produced the highest individual fruit weight of 71.010 g, while the hybrid Snehalata produced the minimum fruit weight (40.770 g). The hybrid Rupali showed statistically significant values as compared to standard hybrid Manisha (48.670 g) and Heemsohna (53.600 g), while both of these standard hybrids were statistically at par to each other. Vooren, *et al.* [9] reported that higher or lower fruit weight may also be ascribed to the varietal characteristics.

3.7. Fruit Size (Fruit Length, Diameter and Girth)

The fruit length ranged from 7.05 cm to 8.91 cm (Table 2). The maximum fruit length was recorded in hybrid Hill Sona (8.91 cm) which was statistically at par with Heemsohna (8.78 cm) and Apoorva (8.41 cm). The minimum fruit length was observed in hybrid PS-61 (7.05 cm) followed by Calyx-111 (7.25 cm). The diameter o fruit ranged from 3.83 cm to 5.00 cm (Table 2). Maximum fruit diameter was recorded in hybrid Apoorva (5.00 cm) followed by Heemsohna (4.94 cm), while the standard hybrid Manisha had the minimum fruit diameter of 3.83 cm followed by Hill Sona (3.89 cm) and these hybrids were statistically at par with each other. It is evident from the Table 2 that the girth of fruits ranged from 14.96 cm to 17.26 cm. The hybrid Apoorva also exhibited maximum fruit girth (17.26 cm) followed by Himraja (17.13 cm) and 7711 (16.80 cm)and also revealed statistically significant value as compared standard hybrid Manisha (14.96 cm) and Heemsohna (15.51 cm). The variation in fruit size in different tomato hybrids reported to be inter varietal associated with the genetic makeup of cultivars and governed by the cell size and intercellular space of the flesh. Earlier studies also have the similar findings for fruit size [10-12].

Table-2. Fruit yield characters of different tomato hybrids under polyhouse condition

Hybrids	No. of marketable fruits per plant	Marketable fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit girth (cm)	Pericarp thickness (cm)	No. of locules per fruit	Marketable fruit yield (q/ha)
Lakshmi	30.57	45.380	7.60	4.73	15.56	3.13	4.33	560.00
Rupali	6.73	71.010	7.58	4.00	15.43	3.50	2.66	180.40
Snehalata	11.40	40.770	7.50	4.10	15.08	4.90	2.66	190.40
Apoorva	24.00	44.300	8.41	5.00	17.26	5.46	4.00	480.00
Hill Sona	11.38	56.840	8.91	3.89	15.06	3.96	3.00	200.00
Raja	11.68	42.940	7.60	4.48	16.33	3.83	2.66	162.00
7711	23.00	62.560	8.25	4.39	16.80	5.66	3.00	440.00
Lucky	6.47	44.360	7.93	4.33	15.56	5.16	3.66	325.20
Jaya (AT-99)	9.54	41.400	8.15	4.23	16.33	5.41	3.66	166.80
PS-61	6.11	54.090	7.05	4.38	16.70	5.25	2.66	132.00
Himraja	58.53	50.400	7.75	4.33	17.13	4.36	3.66	1080.00
Calyx-111	22.00	48.000	7.25	4.15	15.40	5.38	2.66	400.00
Heemsohna (C)	8.00	53.600	8.78	4.94	15.51	4.90	2.00	132.80
Manisha (C)	8.41	48.670	7.69	3.83	14.96	4.73	2.66	149.20
CD at 5%	**1.54**	**9.00**	**0.76**	**0.24**	**0.92**	**0.67**	**0.79**	**35.82**
CV %	**5.41**	**10.66**	**5.79**	**3.34**	**3.43**	**8.53**	**15.20**	**6.49**

3.8. Fruit Pericarp Thickness

The pericarp thickness ranged significantly from 3.13 to 5.66 cm (Table 2). Hybrid No. 7711 recorded the maximum pericarp thickness (5.66 cm) followed by Apoorva (5.46 cm) and Jaya (AT-99) (5.41 cm), while the minimum pericarp thickness was observed (3.13 cm) in Lakshmi. Varieties/hybrids having thick pericarp are suitable for canning and long distance transportation. The pericarp cells have number of starch grain, hence more is the accumulation of assimilates in the pericarp more thick is pericarp. Wahundeniya, *et al.* [5] observed variation in pericarp thickness among different cultivars.

3.9. Number of Locules per Fruit

All tomato hybrids revealed significant differences for number of locules per fruit. The mean values ranged from 2.00 to 4.33 (Table 2). Hybrid Lakshmi recorded maximum number of locules (4.33) followed by Apoorva (4.00), both of these hybrids were statistically significant to standard check Heemsohna (2.00) and Manisha (2.66). The minimum number of locules was produced by Heemsohna (2.00), PS-61 and Raja (2.66), which was also statistically at par with each other. The varieties having higher number of locules were more juicy and were suitable for table purpose. Similar results were also obtained by Wahundeniya, *et al.* [5].

3.10. Marketable Fruit Yield

The highly significant differences for marketable fruit yield were observed among hybrids. The fruit yield per hectare ranged from 132.00 to 1080.00 q/ha (Table 2). Marketable fruit yield is the major determinant variable for selecting a particular variety/hybrid for its commercialization and income generation capability. Among all tomato hybrids the maximum fruit yield per hectare was observed in hybrid Himraja (1080.00 q), which was significantly superior over all the other hybrids followed by Lakshmi (560.00 q) and Apoorva (480.00 q). The hybrid PS-61 gave the lowest marketable fruit yield (132.00 q) followed by check Heemsohna (132.80 q) and Manisha (149.20 q).and were statistically at par with each other for marketable fruit yield. Many folds increase in fruit yield might be due to the varieties/hybrids and growing condition in polyhouse.

In the present investigation, the mean fruit yield per hectare found to be highest in hybrid Himraja succeeded by Lakshmi and Apoorva in comparison to check Heemsohna and Manisha due to its good plant growth, more number of flower clusters, more number of fruits, high percentage of fruit set and low incidence of disease. The similar findings for fruit were also reported by Hussain, *et al.* [13] , Hussain, *et al.* [14], Singh, *et al.* [15], Singh, *et al.* [16] and Mansour, *et al.* [17], there by suggesting that the medium sized and more number of fruits per plant will produce high yield than the hybrids having large sized fruits but less in number.

3.11. Ascorbic Acid Content

The ascorbic acid content varied significantly among all the tomato hybrids. The ascorbic acid content ranged from 12.65 to 15.63 mg/100g (Table 3). The hybrid Heemsohna had the highest Vitamin C content (15.63 mg/100g) followed by Calyx-111 (15.05 mg/100g) and Jaya (AT-99) (15.00 mg/100g), however, statistically these were at par to each other. Hill Sona had the least, with a value of 12.65 mg/100g. Because tomato is mainly consumed in the processed form, using cultivars with high vitamin C.

Table-3. Quality parameters and Disease incidence of different tomato hybrids under polyhouse condition

Hybrids	Ascorbic acid (mg/100g)	TSS (ºBrix)	pH	Titratable acidity (%)	Disease incidence (%)
Lakshmi	14.75	6.50	4.00	0.310	11.25
Rupali	13.20	5.00	3.60	0.623	20.00
Snehalata	14.80	5.33	5.00	0.511	15.00
Apoorva	14.50	5.25	3.56	0.257	13.40
Hill Sona	12.65	5.36	4.10	0.512	28.75
Raja	14.40	5.80	3.90	0.386	30.00
7711	14.86	6.94	4.00	0.588	15.00
Lucky	14.00	7.19	4.50	0.323	20.00
Jaya (AT-99)	15.00	6.65	3.53	0.578	26.25
PS-61	14.15	5.35	3.62	0.593	38.00
Himraja	13.95	7.98	3.50	0.258	05.00
Calyx-111	15.05	6.10	4.00	0.548	17.50
Heemsohna (C)	15.63	4.90	4.50	0.449	35.00
Manisha (C)	14.00	7.50	3.21	0.303	21.00
CD at 5%	**0.89**	**0.59**	**0.19**	**0.12**	**3.54**
CV %	**3.72**	**5.74**	**2.92**	**1.65**	**11.71**

Content is desirable that determines the nutritious status of tomato varieties/hybrids. The ascorbic acid contents of the fruits analyzed in this work are in agreement with Bhatt, *et al.* [18].

3.12. Total Soluble Solids

TSS content in fruits varied between 4.90 to 7.98 ºBrix (Table 3). The maximum total soluble solids were found in hybrid Himraja (7.98 ºBrix) followed by Manisha (7.50 ºBrix) and Lucky (7.19 ºBrix) whereas, the hybrid Heemsohna had the minimum TSS (4.90 ºBrix) followed by Rupali (5.00 ºBrix). The total soluble solids content is one of the most important quality parameters in processing tomato. Varieties/hybrids having higher TSS content are better suited for the preparation of processed products like tomato powder, canned products, ketchup, sauce and chutney. High TSS is desirable to yield higher recovery of processed products. Purkayastha and Mahanta [19] also reported that the total soluble solids content ranged from 3.60 to 5.40 ºBrix.

3.13. pH

Significant differences were noticed among tomato hybrids for pH content (Table 3). The mean value for this trait ranged from 3.21 to 5.00. The maximum pH value was found in hybrid Snehalata (5.00) followed by Heemsohna and Lucky (4.50), while the minimum pH value was recorded in hybrid Manisha (3.21) followed by Himraja (3.50) and Jaya (AT-99) (3.53). The hybrid Snehalata was statistically significant as compared to all other hybrids. These values agree with those of Hazarika and Phookan [7] who reported that pH of the tomato cultivars ranged from 3.56 to 4.33.

3.14. Titratable Acidity

The titratable acidity of tested hybrids significantly ranged from 0.257 to 0.623 %. The maximum titratable acidity was observed in hybrid Rupali (0.623 %), which was statistically significant as compared to standard check. Whereas, the minimum acidity was found in Apoorva (0.257 %) followed by Himraja (0.258 %) and Manisha (0.303 %), however, these hybrids were statistically at par to each other. These findings related to titratable acidity are in accordance with the result of Caliman, *et al.* [20].

3.15. Disease Incidence

Evaluation of these hybrids was also done for disease incidence under polyhouse condition and data is presented in Table 3. All the hybrids significantly differed in relation to disease incidence percent and the mean value for this trait exhibited a range of 5.00 to 38.00 %. Among all the hybrids, Himraja recorded only 5.00 % disease incidence followed by Lakshmi (11.25 %) and Apoorva (13.40 %). These hybrids were statistically significant as compared to standard check Heemsohna (35.00 %) and Manisha (21.00 %), while the maximum disease incidence was observed in hybrid PS-61 (38.00 %). In the present study, Himraja and Lakshmi were found as disease resistant which could be ascribed due to the variation in the genetic makeup of these hybrids. Disease incidence is directly related to the fruit yield. Hybrids which showed less incidence of disease produced higher yield. Likewise, Chellemi, *et al.* [21] studied the performance of tomato hybrids in relation to disease incidence and reported that the incidence of bacterial wilt disease ranged from 0.00 to 83.00 %.

3.16. Economics

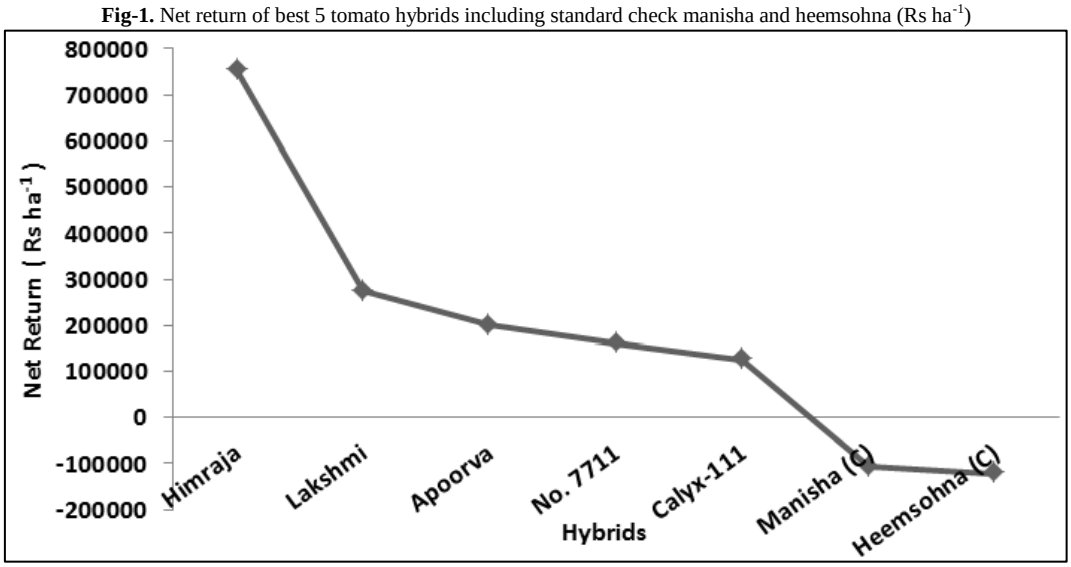
Economics of cultivation of hybrids is presented in Table 4 and Fig.1. Comparative economics revealed that the highest gross return (Rs. 10, 80, 000.00/ha) was obtained from the hybrid Himraja which gave the maximum net return (Rs. 7, 54,475.00/ha). The highest B:C ratio (3.31) was also obtained in the hybrid Himraja. On the basis of economic return, it is apparent that the cultivation of hybrid Himraja was more profitable than the standard check Heemsohna and Manisha. Findings of Alam, *et al.* [22] also support the results of present trial. Based on the present findings, it could be concluded that hybrid Himraja, Lakshmi and Apoorva are more suitable for growing commercially inside the polyhouse under mid hill condition of Uttarakhand, as they not only possess the desirable marketable fruit shape, size and colour for fresh consumption but also have high yield potential and resistance to various biotic/abiotic stresses.

Table-4. Economics of best five tomato hybrids including standard check Manisha and Heemsohna

Hybrids	Cost of cultivation (Rs. ha^{-1})	* Gross Return (Rs. ha^{-1})	Net Return (Rs. ha^{-1})	B:C ratio
Himraja	3,25,525.00	10,80,000.00	7,54,475.00	3.31
Lakshmi	2,86,525.00	5,60,000.00	2,73,475.00	1.95
Apoorva	2,80,525.00	4,80,000.00	1,99,475.00	1.71
No. 7711	2,77,525.00	4,40,000.00	1,62,475.00	1.58
Calyx-111	2,74,525.00	4,00,000.00	1,25,475.00	1.45
Manisha (C)	2,55,715.00	1,49,200.00	(-)1,06,515.00	(-)0.58
Heemsohna (C)	2,54,485.00	1,32,800.00	(-)1,21,685.00	(-)0.52

*****Selling price of the produce: Rs. 1000.00 per quintal

Fig-1. Net return of best 5 tomato hybrids including standard check manisha and heemsohna (Rs ha^{-1})



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