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Performance evaluation and character association studies in arid region greenhouse tomato hybrids

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ABSTRACT

Alike in other areas, greenhouse cultivation is getting special impetus in arid regions owing to providing favourable micro-climate, besides protecting crops from various external crop limiting factors which causes considerable losses to productivity. Cultivar selection is among the most critical aspect for successful greenhouse cultivation. In order to select appropriate cultivar for peculiar arid conditions, the performance of twenty indeterminate tomato hybrids were evaluated under greenhouse condition at Jodhpur during September to April, 2016-17. The performance of hybrids was assessed for their growth, yield and quality characteristics. Results obtained from the study reveal that the performance of tomato hybrids differ significantly for different growth and yield parameters among them. Shoot (leaf + stem) biomass production showed wide variation among the hybrids, ranging from 162g (IA05) to 225.7g (Avtar) per plant. Fruit yield also varied widely (2.36 kg to 4.94 kg plant^{-1}). Hybrid Myla (4.94 kg) was found superior in per plant fruit yield, followed by TR4343 (4.71kg) and TR4266 (4.65kg). Significant differences were also observed for fruit quality attributes such as pericarp thickness, total soluble solids, pH and EC in different hybrids. The character association analyses show that the yield per plant had significant positive correlation with average fruit weight (0.72), fruit diameter (0.50) and pericarp thickness (0.45). The highest fruit number was found in TR4266 (68.4), which had statistically similar per plant fruit yield with Myla. Whereas, the highest average fruit weight (166.8g), though lowest fruit number (40.3) was recorded in TR4293. The high mean values of the yield associated parameters in high-yielding hybrids Myla, TR4343, TR4266, TR4293 corroborates their production potential under greenhouse in arid regions.

Key words: *Solanum lycopersicum*, yield, greenhouse, hybrids, arid region.

Tomato (*Solanum lycopersicum* L.) occupies prominent position among the vegetables because of nutritional and economical importance. Tomato is universally treated as protective food because it is rich in vitamins, minerals and organic acids. In India, tomato is grown over 0.88 million hectares area with an annual production of 18.7 million metric tonnes, accounting to an average productivity of 21.2 tonnes per hectare; it has 11.5 percent share in total vegetable production (NHB, 16).

The arid regions are characterized by scanty and erratic rainfall coupled with low ground water reserve, intensive radiation and high evaporative demand. In North-western parts of arid regions of India, tomato production is limited by various biotic and abiotic stresses (Khan and Samadia, 11). Tomato production in arid region is season bound and has very low productivity. In open field condition, rainy season tomato crop suffers due to high prevalence of pests and diseases, besides high temperature during prolong dry period sometimes causes flower and fruit drop. Whereas, in the *rabi* season sub-optimal temperatures adversely affect the early vegetative growth of tomato plants which consequently impact the significant yield reduction. However, with greenhouse technology, the production can be taken round the year and productivity could be enhanced. Protected cultivation is breakthrough technology with proven high potential to provide more produce per unit used area, water, nutrient and labour. Controlled environment agriculture is possibly the most intensive method of crop production, conservative of water and land, and also protective of the environment (Jensen, 7). The natural environment is modified under greenhouse to the suitable conditions for optimum plant growth which ultimately helps in the production of quality tomatoes suitable for exports and domestic consumption (Singh and Sirohi, 18). Since, the demand of fresh tomatoes remains high round the year, to ensure their regular supply greenhouse cultivation can be a viable option in these areas.

Tomato is one of the most important and highly remunerative vegetable crops for greenhouse cultivation. Among the different pre-requisites, selection of the most suitable cultivar (indeterminate hybrid) for particular regions is very essential for successful tomato culture in greenhouse (Arora *et al.*, 1). If the inside environment remained same across the regions, as possible only under automated greenhouses, a particular hybrid can be used.

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However, the most of commercial greenhouses in North-western arid and semi-arid plains are either naturally ventilated or semi-automated (evaporative cooling based), and it is likelihood that the influence of ambient environments on inside environments. Hence, it is necessary to select suitable tomato cultivars for these areas.

Previous greenhouse studies showed that the performance of hybrids vary based on location. For instance, in different studies the outperforming hybrid for Hisar condition was HYB-99K-126 (Arora *et al*., 1), for Lucknow condition was Himsona (Singh *et al*., 10) and for Ludhiana was HS-18 (Jindal *et al*., 8). Besides, the upcoming of new greenhouse hybrids to replace the older one also necessitates the evaluation of new hybrids performance under particular environment. Furthermore, the area under protected cultivation is taking leap in arid regions, and hence requires an appropriate package of practices for greenhouse cultivation. So far, there is no such study done under western arid plains, where greenhouse cultivation is recent innovation and getting momentum. Systematic study on performance evaluation of tomato hybrids is of great importance for current and future agronomic improvement of this crop. Therefore, the present study was aimed to assess the performance and character association in indeterminate tomato hybrids under polyhouse under Jodhpur conditions of arid western region of India.

MATERIALS AND METHODS

In present study, twenty-indeterminate tomato hybrids, acquired from various sources, were evaluated in greenhouse conditions during September to April, 2016-2017. The polyethylene covered (200µm thickness) 500m^2 greenhouse is located at central research farm at ICAR-CAZRI, Jodhpur (26° 15' N latitude and 72°59' E longitude and at an elevation of 231 m above MSL). The data pertaining to various micro-climatic parameters inside the greenhouse during crop growth period was recorded by WS-GP1 automated weather station (Delta T devices, Cambridge, UK) and presented in Table 1.

The seeds of tomato hybrids were sown in 98-celled pro-trays in nutrient enriched coco-peat media, and twenty-one days old seedlings were transplanted in a randomized block design (RBD) with four replications spaced at 60 cm x 50 cm in paired row on 95cm wide raised beds. The common package of practices for successful cultivation of the crop raising was followed.

Five randomly selected representative plants from each hybrid in each replication were tagged for the record of observations on different growth and yield related parameters. Fruit quality parameters were recorded from ripe, firm and uniform fruits during peak harvesting period. The fruit yield, number of fruits, and mean fruit weight were recorded on the selected plants. Fruit length, diameter, pericarp thickness and pedicle scar diameter were measured with the help of digital Vernier caliper.

The fruit juice was extracted separately from each hybrid and were used to estimate pH and EC by digital pH and EC meter. The TSS was determined by digital refractometer at ambient temperature. At the end of the experiment, each tagged plant was separated into leaf and stem and their tissues were dried in a forced-air oven at 80^{0}C until constant weight for biomass determination. Shoot biomass was equal to the sum of aerial vegetative plant parts (leaves and stems).

Data were analyzed for variance in a Randomized Block Design with four replications according to Gomez and Gomez (3), and mean performance and simple correlations for various characters were worked out and tested for significance.

Table 1. Climatic parameters recorded by automated weather station inside the greenhouse.

Month-Year	Temperature (ºC)			Humidity (%)			Radiation (wm^{-2})		
	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
Sep.-2016	23.5	36.9	29.5	23.4	95.5	73.8	4.0	696	311
Oct.-2016	16.8	34.9	26.5	17.2	90.4	76.4	1.0	616	257
Nov.-2016	12.5	33.3	20.4	16.3	97.9	73.8	1.0	458	195
Dec.-2016	10.9	29.0	17.9	18.8	97.9	75.5	5.0	307	141
Jan.-2017	10.3	27.9	16.3	15.3	97.4	76.6	1.0	474	134
Feb.-2017	11.8	33.6	20.1	9.7	96.8	64.9	2.0	518	230
Mar.-2017	12.7	35.1	25.2	8.0	90.1	52.3	1.0	687	278
Apr.-2017	17.0	36.7	31.2	3.7	63.5	24.9	1.0	918	343

RESULTS AND DISCUSSION

The analysis of variance of all treatments were found significant for all the characters under the study. Mean sum of squares were also found significant for all treatment because all hybrids are genetically diverse from each other and showed significant variation.

Growth and Yield Performance

The greenhouse tomatoes are of indeterminate growth habit, need regular removal of axillary shoots to avoid the imbalance between source and sink (Heuvelink, 5). The shoot dry biomass production varied widely among different hybrids and presented as shoot dry weight (Table 2). The highest shoot dry weight was recorded in hybrid Avtar (225.7g plant^{-1}), which differed significantly from other hybrids except to that of Myla, PPHT-1, IA03 and TR4266. The lowest shoot dry weight was observed in hybrid IA05 (162.3g plant^{-1}) and at par with UG1205, US2853, TR4293, US920 and IA01. Similar to shoot dry weight, per plant fruit yield was also varied widely among different hybrids; the difference in the highest yielding hybrid Myla (4.94 kg plant^{-1}) was more than two-fold to that of lowest yielding hybrid UG12T-293 (2.36 kg plant^{-1}). Some other hybrids like TR4266 and TR4343 also gave higher per plant fruit yield with no statistical difference with highest yielding hybrid Myla. The variation in shoot dry weight as well as per plant fruit yield was also noticed by Kumar *et al.* (13) in greenhouse tomatoes; where variation in fruit yield was in response to the genotypes of rootstocks. Similar observation for yield per plant in greenhouse tomato hybrids were reported by (Arora *et al*., 1 and Singh *et al.*, 19).

The yield attributing characters such as number of fruits per plant and average fruit weight were also ranged widely from 40.3 (TR4293) to 68.4 (TR4266) and 53.9g (UG12T-293) to 166.8g (TR4293), respectively (Table 2). This shows that the hybrid TR4293, which had highest average fruit weight gave the lowest per plant fruit number; showing inverse relation between the two parameters, though this relation was inconsistent for many other hybrids. Similar to our results, in a greenhouse study at Hisar, Arora *et al.* (1) found that the tomato hybrid Compary, which produced maximum number of fruit per plant (119) had minimum average fruit weight (52g). Fruit length and fruit diameter determine the fruit shape, and can vary with the genotypes (Kumar *et al*., 14) as in present study also found significant variations for these parameters among different hybrids (Table 3). Fruit length ranged from 4.91cm to 7.28cm among the hybrids. The highest fruit length was recorded in US920 (7.28 cm) followed by PPHT-2 (7.24 cm), with no significant difference between these two hybrids. Fruit diameter was recorded highest in hybrid TR4343 (7.35 cm) followed by TR4293 and UG96504 with no apparent difference among them, but it was significantly different from other hybrids in the study. Significant difference for average fruit weight in tomato hybrids was also noted by Jana and Bhattacharya (6) and Arora *et al.* (1), which supposedly varied based on genetic potential of hybrid and location of the study. On physical appearance basis and the basis on fruit length and fruit girth, it was noted that hybrids US920 was of oblong shape whereas, hybrid TR4343 was flat round in shape. The variation in fruit length and diameter in different tomato hybrids is reported to be associated with their genetic makeup, and governed by the cell size and intercellular space of the flesh.

Pedicle scar diameter among the tomato hybrids ranged from 10.7 mm to 18.3 mm (Table 3). Least value for pedicle scar diameter was recorded in hybrid PPHT-2 (10.7 mm). The rate of respiration and process of ripening in tomato is influenced by pedicle scar diameter (Paul *et al*., 17), hence hybrids with

Table 2. Growth and yield performance of indeterminate tomato hybrids in greenhouse condition.

Hybrids	Shoot dry weight (g plant^{-1})	Fruits number (plant^{-1})	Average fruit weight (g)	Fruits yield (kg plant^{-1})
PPHT-1	217.0	48.1	118.9	4.11
PPHT-2	188.0	45.1	110.4	3.82
UG12T-293	210.7	64.4	53.9	2.36
UG96504	213.7	45.6	106.4	3.49
UG1205	164.0	62.2	80.6	3.29
Abhirang	211.7	42.5	130.0	3.90
US920	170.3	63.4	84.9	3.54
US2853	185.7	55.2	104.8	4.14
Avtar	225.7	51.5	94.9	3.24
IAR03	220.6	49.3	86.6	2.83
IA05	162.3	47.1	85.7	2.61
IA01	173.3	510	98.0	3.17
IA08	198.3	52.5	78.9	2.42
IA06	196.5	49.6	96.6	3.50
IA07	193.3	59.8	110.7	4.42
TR4266	217.3	68.4	95.1	4.65
TR4293	211.7	40.3	166.8	4.52
TR4343	209.3	46.5	143.7	4.71
TR4769	169.7	43.4	122.3	3.83
Myla	222.3	61.92	113.7	4.94
SEm±	2.80	0.58	1.38	0.10
CD(P=0.05)	8.05	1.66	3.96	0.27

Table 3. Fruit quality of indeterminate tomato hybrids in greenhouse condition.

Hybrids	Fruit length (cm)	Fruit diameter (cm)	Pedicle scar diameter (mm)	Pericarp thickness (mm)	Total soluble solids (%)	pH	EC
PPHT-1	5.40	5.91	11.7	7.31	3.80	4.07	3.99
PPHT-2	7.24	6.54	10.7	7.18	3.83	3.92	4.24
UG12T-293	4.91	5.51	15.3	6.47	4.47	4.00	4.68
UG96504	6.29	7.07	17.4	8.81	4.27	4.22	5.12
UG1205	5.75	5.61	14.7	8.51	3.76	4.15	4.79
Abhirang	5.45	6.24	13.6	8.68	3.83	4.19	4.49
US920	7.28	5.40	14.3	8.32	4.30	4.36	4.00
US2853	6.36	6.37	16.7	10.16	4.00	4.23	4.37
Avtar	6.55	6.72	18.3	7.94	4.20	4.35	4.67
IAR03	6.41	5.72	15.3	7.45	3.53	4.15	4.20
IA05	5.06	6.08	13.7	8.13	4.17	4.10	4.88
IA01	5.42	4.67	13.3	6.72	4.00	4.24	4.82
IA08	5.12	6.09	13.0	8.15	4.03	4.12	4.69
IA06	5.16	5.80	16.0	9.14	3.70	4.34	4.72
IA07	5.26	6.30	14.3	8.71	3.60	4.20	4.77
TR4266	5.45	6.43	12.4	9.30	3.72	4.28	4.58
TR4293	5.99	7.23	17.1	9.01	3.80	4.27	5.37
TR4343	6.04	7.35	14.0	9.42	4.20	4.43	5.09
TR4769	5.51	6.59	11.7	10.00	3.90	4.34	4.91
Myla	5.50	6.62	16.3	8.45	4.27	4.21	4.86
SEm±	0.17	0.19	0.87	0.43	0.17	0.07	0.19
CD(P=0.05)	0.50	0.55	2.50	1.25	0.50	0.20	0.54

smaller pedicle scar diameter are preferred for better shelf life. Therefore, there is possibility of having maximum shelf life in hybrid PPHT-2 due to small pedicle scar diameter. Moreover, small pedicle scar is preferred from processing and fresh consumption point of view in tomato (Joshi and Kholi, 9). Pericarp thickness varied from 6.47 mm to 10.16 mm, the maximum pericarp thickness was noted in hybrid US2853 (10.16 mm) followed by TR4769 (10.00 mm) and these hybrids were at par with each other. Since, pericarp thickness is associated with accumulation of assimilates. The variation in pericarp thickness among different tomato hybrids were also noted by Kumari *et al.* (15) and Hazarika and Phookan (4).

Total soluble solids (TSS) is an important fruit quality parameter which decides the utility of the hybrid for processing purpose. Significant differences were observed for TSS content in different tomato hybrids, and it ranged from 3.53 % to 4.47% (Table 3). The highest TSS content was recorded in hybrid UG12T-293 (4.47%) which statistically differed with other hybrids. The significant differences were also observed for TSS content in different greenhouse tomato hybrids in different studies (Cheema *et al*., 2 and Jindal *et al.*, 8). Fruit juice pH of the cultivars varied from 3.92 to 4.43; hybrid TR4343 recorded the highest value, which differed with others. Hazarika and Phookan (4) also reported wide range for juice pH from 3.56 to 4.33 among different tomato hybrids under polyhouse conditions. Additionally, we reported a wide range in fruit EC which varied from 3.99 (PPHT-1) to 5.12 (UG96504) among the tomato hybrids (Table 3).

The hybrids Myla, TR4266, TR4293 and IA07 were the best performing hybrids under greenhouse condition in present study based on their per se performance.

Character association

The correlation matrix derived from different parameters under study reveal that the fruit yield per plant was positively and significantly correlated with fruit diameter (0.50), pericarp thickness (0.45), pH (0.29) and average fruit weight (0.72) Table 4.

Table 4. Character association in tomato hybrids in greenhouse condition.

Characters	SDW (g)	FL (cm)	FD (cm)	PS (mm)	PT (mm)	TSS (%)	pH	EC	NFPP	AFW (g)	YPP (kg)
SDW (g)	1.00	0.19	0.41**	0.18	-0.17	0.01	-0.07	0.06	-0.11	0.13	0.08
FL(cm)		1.00	0.21	0.12	0.02	0.03	0.05	-0.29*	-0.11	0.13	0.12
FG (cm)			1.00	0.22	0.43**	0.01	0.17	0.32*	-0.34**	0.60**	0.50**
PS (mm)				1.00	0.07	0.11	0.22	0.24	0.05	0.00	-0.00
PT (mm)					1.00	-0.17	0.43**	0.24	-0.08	0.39**	0.45**
TSS (%)						1.00	0.10	0.14	0.14	-0.17	-0.12
pH							1.00	0.26*	-0.01	0.27*	0.29*
EC								1.00	-0.19	0.28*	0.13
NFPP									1.00	-0.60**	0.02
AFW(g)										1.00	0.72**
YPP (kg)											1.00

*, ** Significant at 1 and 5% levels.
SDW: Shoot dry weight, FL: Fruit length, FG: Fruit girth, PSD: Pedicle scar diameter, TSS: Total soluble solids, pH: pH of fruit juice, EC: EC of fruit juice, NFP: Number of fruits per plant, AFW: Average fruit weight, YPP: Yield per plant

Souza *et al.* (20) observed high positive significant correlation between two economically important traits i.e. fruit yield per plant and average fruit weight. According to Kaushik *et al*. (10) and Khapte and Jansirani (12) fruit yield positively correlates with fruit diameter and with pericarp thickness in tomato, respectively. Further, average fruit weight was found to be positively and significantly correlated with fruit diameter (0.60), pericarp thickness (0.39), pH (0.27) and EC (0.28), however, it was negatively and significantly correlated with number of fruits per plant (-0.60). Number of fruits per plant had negative and significant correlation with fruit diameter (-0.34). EC was positively and significantly correlated with fruit diameter (0.32), pH (0.26) and negatively associated with fruit length (-0.29). The pericarp thickness was positively and significantly correlated with fruit diameter (0.43) whereas, fruit diameter with dry plant biomass (0.41). Khan and Samadia (11) also reported the correlation between pericarp thickness and fruit diameter in tomato genotypes. Total soluble solids and pedicel scar diameter were not associated with any other characters in present study.

From the study, it is clear that tomato hybrids vary significantly for different growth and yield parameters. Maximum yield per plant was recorded in hybrid Myla (4.94kg) followed by TR4343 (4.71kg), TR4266 (4.65kg), IA07 (4.42 kg), these hybrids outperformed compared to other hybrids with respect to yield and related traits based on their performance under greenhouse conditions in arid regions. Further, the character association results show that the yield per plant had positive significant correlation with fruit diameter (0.50), pericarp thickness (0.45), pH (0.29) and average fruit weight (0.72). The higher fruit yield and these yield associated characters in the some of the outperforming hybrids indicate that the performance of these superior hybrids are consistent, and shall be given due consideration for greenhouse tomato cultivation in arid regions. Thus, the tomato production in greenhouse could enhance production and productivity, besides making efficient use of resources in arid regions.

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