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Evaluation of Tomato (*Solanum lycopersicum* L.) Genotypes for Growth, Yield and Quality Traits at Different Planting Density

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A B S T R A C T

An experiment on Tomato Genotypes at different planting density was conducted during January to May 2020 in Research Field, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.) India. The results of the present investigation, regarding the evaluation of four genotypes i.e. (AVTO – 1706, AVTO – 1707, Arka Samrat and Pusa Ruby) of tomato in four planting densities i.e. (0.2, 0.3, 0.4 and 0.5 m) for plant growth, fruit yield and quality of Tomato, have been discussed and interpreted in the light of previous research work done in India and abroad. The experiment was conducted in 4x4 Factorial Randomized block design with 4Genotypes of Tomato obtained from different sources, were each genotype replicated thrice in different planting densities. From the present experimental findings it is found that the genotype G_4 (Pusa Ruby) followed by G_3 (Arka Samrat) and planting density D_4 (0.5 m) followed by D_3 (0.4 m) was found suitable in terms of growth, quality and yield per plant. In terms of yield/plot and per hectare, planting density D_1 (0.2 m) was best due to more number of plants per plot and per hectare area. In terms of economics maximum gross, net return and cost benefit ratio was recorded in genotype G_4 (Pusa Ruby) and minimum in G_1 (AVTO - 1706).

Introduction

Tomato (*Solanum lycopersicum* L.) Wettsd, (2n = 2x = 24) is one of the most popular and widely grown vegetable crops of the world next to potato. The genus Solanum consists of annual or short lived perennial herbaceous, typical day neutral plant and warm season crops. Tomato is reasonably susceptible to frost as well as high temperature but it is grown in a variety of climatic conditions.

Tomato production is affected with various factors like insects, diseases, low yields, crop failures, heat complexes and salinity that need systematic breeding effort.

Considering the importance of tomato as a potential vegetable both as domestic consumption as well as export market, it is important to increase its productivity along with desirable attributes through genetic manipulation (Iregna Tasisa *et al.*, 2011). In

this context it is necessary to identify plant characters or traits important to the development programme.

The present research is conducted to assess the genotypes for growth, yield and quality components with different planting densities. Yield is a complex character controlled by a large number of contributing characters and their interactions. A study of genotypes with planting density between different growth and yield characters provides an idea of association that could be effectively exploited to formulate selection strategies for improving yield components. It would be desirable to consider the relative magnitude of association of various characters with yield, therefore proper understanding of the genotypes in different planting density helps in identifying the best genotypes with best suited density for benefiting the farmers.

Materials and Methods

The present Experiment was conducted in 4x4 Factotial Randomized Block Design (FRBD), with four genotypes *i.e.* (AVTO – 1706, AVTO – 1707, Arka Samrat and Pusa Ruby) of tomato in four planting densities *i.e.* (0.2, 0.3, 0.4 and 0.5 m) total 16treatments, replicated thrice with, in the Research field, Department of Horticulture, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj during January to May, 2020.

Climatic condition in the experimental site

The area of Prayagraj district comes under subtropical belt in the south east of Utter Pradesh, which experience extremely hot summer and fairly cold winter. The maximum temperature of the location reaches up to 46^{o} C- 48^{o} C and seldom falls as low as 4^{o}C- 5^{o}C. The relative humidity ranges between 20 to 94 %. The average rainfall in this area is around 1013.4 mm annually. However, occasional precipitation is also not uncommon during winter months.

Results and Discussion

The present investigation entitled “Evaluation of Tomato (*Solanum lycopersicum* L.) Genotypes for growth, yield and quality traits at different planting density” was carried out during January to May, 2020 in Research Field, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.) India. The results of the present investigation, regarding the evaluation of genotypes of Tomato for growth, yield and quality parameters in different planting densities, have been discussed and interpreted in the light of previous research work done in India and abroad.

The results of the experiment are summarized below.

Growth Parameters

The data on growth parameters are given in table 1.1 it is clear from the table that all the treatment differed significantly for all growth parameters. Significantly maximum. Plant height 60.15, was noticed in the interaction effect of D_4G_4(0.5 m x Pusa Ruby), followed by D_3G_4(0.4 m x Pusa Ruby) with 55.90 cm, whereas minimum plant height 43.21 cm, was recorded in, D_1G_2 (0.2 m x AVTO - 1707). Similarly in for Number of branch maximum 12.90 branch, was recorded in D_4G_4 (0.5 m x Pusa Ruby), followed by D_4G_3 (0.5 m x Arka Samrat) with 11.44 branch, whereas minimum number of branch 8.12, was observed in, D_2G_1 (0.2 m x AVTO - 1706). Maximum plant height and Number of branches in wider spacing is may be due to the availability of more space for plant growth, better light

distribution and utilization pattern due to wider spacing. Significantly increase plant height with increased plant spacing previously also reported by Singh *et al.,* (2005) and Bhattarai *et al.,* (2015) in Tomato.

In earliness parameter i.e. Days to first flowering significantly, minimum days for first flowering45.32 days, was recorded in interaction effect D_4G_3 (0.5 m x Arka Samrat), followed by D_4G_1 (0.5 m x AVTO - 1706) with 45.42 days, whereas maximum days for first flowering 58.51 days, was observed in, D_1G_4 (0.2 m x Pusa ruby). Similarly in days to 50% flowering, minimum 50.43 days, was noticed in interaction effect D_4G_3(0.5 m x Arka Samrat), followed by D_4G_1(0.5 m x AVTO - 1706) with 51.60 days, whereas maximum 63.64 days, was observed in, D_1G_4 (0.2 m x Pusa ruby).The early flowering in wider spacing is may be attributed to better light distribution and utilization pattern due to wider spacing Ambroszczyk *et al.,* (2008) and availability of more nutrients per unit area Jiang *et al.,* (2013) in Tomato. In early fruit picking for minimum days for first fruit picking65.46 days, was recorded in interaction effect D_4G_3(0.5 m x Arka Samrat), followed by D_4G_1(0.5 m x AVTO - 1706) with 67.01 days, whereas maximum 80.50 days, was observed in, D_1G_4 (0.2 m x Pusa ruby).The early fruit picking in wider spacing is may be attributed to better light distribution and utilization pattern due to wider spacing Ambroszczyk *et al.,* (2008) and availability of more nutrients per unit area Jiang *et al.,* (2013)in Tomato.

Table.1.1 Plant Height, Number of primary branches, days to first flowering, days to 50% flowering and polar diameter of different genotypes of Tomato in different planting density

Genotypes	Plant height 120 DAS				
	Planting density				Mean G
	D_1	D_2	D_3	D_4	
G_1	43.81	45.73	46.17	48.74	46.11
G_2	43.21	43.47	44.42	47.44	44.63
G_3	44.86	46.92	48.84	50.92	47.88
G_4	50.62	52.53	55.90	60.15	54.80
Mean D	45.62	47.16	48.83	51.81	
Factors			F-Test	SE(d)	C.D.
Factor(G)			S	0.273	0.561
Factor(D)			S	0.273	0.561
Factor(G X D)			S	0.547	1.122

Genotypes	Days to first flowering				
	Planting density				Mean G
	D_1	D_2	D_3	D_4	
G_1	49.61	48.29	47.11	45.42	47.60
G_2	55.35	53.92	52.27	50.42	52.99
G_3	50.58	49.44	47.79	45.32	48.28
G_4	58.51	56.94	55.53	53.41	56.09
Mean D	53.51	52.14	50.67	48.64	
Factors			F-Test	SE(d)	C.D.
Factor(G)			S	0.665	1.365
Factor(D)			S	0.665	1.365
Factor(G X D)			S	1.330	N/A

Genotypes	Number of branches 120 DAS				
	Planting density				Mean G
	D_1	D_2	D_3	D_4	
G_1	8.50	8.12	8.48	9.66	8.69
G_2	8.48	9.01	9.27	10.29	9.26
G_3	9.28	10.11	10.72	11.44	10.38
G_4	9.86	10.85	11.35	12.90	11.24
Mean D	9.03	9.52	9.95	11.07	
Factors			F-Test	SE(d)	C.D.
Factor(G)			S	0.086	0.176
Factor(D)			S	0.086	0.176
Factor(G X D)			S	0.172	0.352

Genotypes	Days to 50% flowering				
	Planting density				Mean G
	D_1	D_2	D_3	D_4	
G_1	57.02	54.87	53.22	51.60	54.17
G_2	61.81	60.09	58.31	56.37	59.14
G_3	56.23	54.92	53.01	50.43	53.64
G_4	63.64	62.58	61.31	58.55	61.52
Mean D	59.67	58.11	56.46	54.23	

Factors	F-Test	SE(d)	C.D.
Factor(G)	S	0.668	1.370
Factor(D)	S	0.668	1.370
Factor(G X D)	NS	1.335	N/A

Genotypes	Days to first fruit picking				
	Planting density				Mean G
	D_1	D_2	D_3	D_4	
G_1	75.25	72.29	69.37	67.01	70.98
G_2	79.47	76.57	73.79	71.40	75.30
G_3	72.77	71.14	68.66	65.46	69.50
G_4	80.50	78.46	77.06	73.41	77.35
Mean D	76.99	74.61	72.22	69.32	

Factors	F-Test	SE(d)	C.D.
Factor(G)	S	0.667	1.369
Factor(D)	S	0.667	1.369
Factor(G X D)	NS	1.334	N/A

Table.1.2 Polar diameter, Radial diameter, Fruit girth, avg. fruit weight, number of fruits/cluster and number of fruits/plant of different genotypes of Tomato in different planting density

Genotypes	Polar diameter (cm)				
	Planting density				Mean G
	D_1	D_2	D_3	D_4	
G_1	5.01	5.17	5.22	5.36	5.19
G_2	4.99	5.14	5.23	5.24	5.15
G_3	4.22	4.43	4.56	4.88	4.52
G_4	5.11	5.13	5.42	5.57	5.30
Mean D	4.83	4.96	5.10	5.26	

Factors	F-Test	SE(d)	C.D.
Factor(G)	S	0.058	0.120
Factor(D)	S	0.058	0.120
Factor(G X D)	NS	0.117	N/A

Genotypes	Radial diameter (cm)				
	Planting density				Mean G
	D_1	D_2	D_3	D_4	
G_1	5.33	5.41	5.59	5.75	5.52
G_2	5.12	5.18	5.37	5.48	5.28
G_3	4.62	5.06	4.98	5.16	4.95
G_4	5.26	5.50	5.87	5.99	5.65
Mean D	5.08	5.28	5.45	5.59	

Factors	F-Test	SE(d)	C.D.
Factor(G)	S	0.075	0.154
Factor(D)	S	0.075	0.154
Factor(G X D)	NS	0.150	N/A

Genotypes	Fruit girth (cm)				
	Planting density				Mean G
	D_1	D_2	D_3	D_4	
G_1	11.97	12.17	12.47	13.33	12.48
G_2	10.62	11.63	12.10	12.61	11.74
G_3	11.08	11.10	11.62	12.27	11.51
G_4	12.22	12.71	13.59	14.50	13.25
Mean D	11.47	11.90	12.44	13.17	

Factors	F-Test	SE(d)	C.D.
Factor(G)	S	0.122	0.251
Factor(D)	S	0.122	0.251
Factor(G X D)	S	0.244	0.502

Genotypes	Avg. fruit weight (g)				
	Planting density				Mean G
	D_1	D_2	D_3	D_4	
G_1	57.05	59.74	63.88	67.53	62.05
G_2	57.34	61.99	66.41	71.40	64.28
G_3	59.97	64.02	68.87	74.57	66.85
G_4	69.01	72.72	76.83	82.06	75.15
Mean D	60.84	64.61	68.99	73.89	

Factors	F-Test	SE(d)	C.D.
Factor(G)	S	0.199	0.409
Factor(D)	S	0.199	0.409
Factor(G X D)	S	0.399	0.818

Genotypes	Number of fruit/cluster				
	Planting density				Mean G
	D_1	D_2	D_3	D_4	
G_1	3.73	3.87	4.06	4.23	3.97
G_2	3.78	3.38	3.92	4.29	3.84
G_3	4.18	4.25	4.51	4.62	4.39
G_4	4.56	5.06	5.08	5.51	5.05
Mean D	4.06	4.14	4.39	4.66	

Factors	F-Test	SE(d)	C.D.
Factor(G)	S	0.094	0.192
Factor(D)	S	0.094	0.192
Factor(G X D)	NS	0.187	N/A

Genotypes	Number of fruit/plant				
	Planting density				Mean G
	D_1	D_2	D_3	D_4	
G_1	17.87	19.12	19.76	20.43	19.29
G_2	18.54	19.19	19.43	21.09	19.56
G_3	19.89	20.55	21.11	21.62	20.79
G_4	23.85	23.14	25.04	26.62	24.66
Mean D	20.03	20.50	21.33	22.44	

Factors	F-Test	SE(d)	C.D.
Factor(G)	S	0.280	0.574
Factor(D)	S	0.280	0.574
Factor(G X D)	NS	0.559	N/A

Table.1.2.1 Yield/plant (kg), yield/plot and Yield/ha of different genotypes of Tomato in different planting density

Genotypes	Yield/plant (kg)				
	Planting density				Mean G
	D_1	D_2	D_3	D_4	
G_1	1.01	1.14	1.20	1.30	1.19
G_2	1.06	1.18	1.20	1.50	1.25
G_3	1.19	1.31	1.40	1.60	1.39
G_4	1.64	1.68	1.90	2.10	1.85
Mean D	1.22	1.32	1.40	1.65	

Factors	F-Test	SE(d)	C.D.
Factor(G)	S	0.022	0.045
Factor(D)	S	0.022	0.045
Factor(G X D)	S	0.044	0.090

Genotypes	Yield/plot (kg)				
	Planting density				Mean G
	D_1	D_2	D_3	D_4	
G_1	55.55	39.90	35.28	30.14	40.21
G_2	58.18	41.30	49.02	33.00	45.37
G_3	65.45	45.85	40.60	35.42	46.83
G_4	90.20	58.80	53.76	47.96	62.68
Mean D	67.34	46.46	44.66	36.63	

Factors	F-Test	SE(d)	C.D.
Factor(G)	S	0.726	1.489
Factor(D)	S	0.726	1.489
Factor(G X D)	S	1.451	2.978

Genotypes	Yield/ha (tonnes)				
	Planting density				Mean G
	D_1	D_2	D_3	D_4	
G_1	59.02	42.39	37.48	32.02	42.72
G_2	61.93	43.87	52.08	35.06	48.23
G_3	69.53	48.71	43.13	37.63	49.75
G_4	95.83	62.47	57.12	50.95	66.59
Mean D	71.57	49.36	47.45	38.91	

Factors	F-Test	SE(d)	C.D.
Factor(G)	S	0.771	1.583
Factor(D)	S	0.771	1.583
Factor(G X D)	S	1.543	3.166

Table.1.3 Total soluble solid, Ascorbic acid and benefit cost ratio of different genotypes of Tomato in different planting density

Genotypes	Total Soluble Solids (°Brix)				
	Planting density				Mean G
	D_1	D_2	D_3	D_4	
G_1	4.73	4.54	4.84	5.06	4.79
G_2	5.26	5.24	5.31	5.44	5.31
G_3	5.91	5.51	5.78	5.87	5.76
G_4	4.16	4.16	4.22	4.32	4.21
Mean D	5.01	4.86	5.03	5.17	

Factors	F-Test	SE(d)	C.D.
Factor(G)	S	0.103	0.212
Factor(D)	S	0.103	0.212
Factor(G X D)	NS	0.206	N/A

Genotypes	Ascorbic acid (mg/100g)				
	Planting density				Mean G
	D_1	D_2	D_3	D_4	
G_1	20.19	21.59	22.86	21.48	21.53
G_2	20.34	21.57	22.52	24.07	22.12
G_3	23.74	24.59	24.64	25.71	24.67
G_4	24.14	25.87	24.91	26.22	25.28
Mean D	22.10	23.40	23.73	24.37	

Factors	F-Test	SE(d)	C.D.
Factor(G)	S	1.215	2.482
Factor(D)	S	1.215	2.482
Factor(G X D)	NS	2.430	N/A

Treatments	B:C ratio	Treatments	B:C ratio
G_1D_1	3.33	G_3D_1	4.57
G_1D_2	2.49	G_3D_2	3.31
G_1D_3	2.31	G_3D_3	3.03
G_1D_4	2.07	G_3D_4	2.74
G_2D_1	3.49	G_4D_1	6.43
G_2D_2	2.58	G_4D_2	4.32
G_2D_3	3.21	G_4D_3	4.09
G_2D_4	2.26	G_4D_4	3.77

Yield parameters

The data on growth parameters are given in table 1.2 and 1.2.1 it is clear from the table that all the treatment differed significantly for all yield parameters. Significantly maximum polar diameter 5.57 cm, was recorded in interaction effect D_4G_4 (0.5 m x Pusa ruby), followed by D_3G_4 (0.4 m x Pusa ruby) with 5.42 cm, whereas minimum diameter 4.22 cm, was observed in, D_1G_3 (0.2 m x Arka Samrat). Similarly in maximum radial diameter5.99 cm, was recorded in interaction effect D_4G_4(0.5 m x Pusa ruby), followed by D_3G_4(0.4 m x Pusa ruby) with 5.87 cm, whereas minimum radial diameter 4.62 cm, was observed in, D_1G_3 (0.2 m x Arka Samrat) and in terms of fruit girth, maximum 14.50 cm, was recorded in interaction effect D_4G_4 (0.5 m x Pusa ruby), followed by D_3G_4 (0.4 m x Pusa ruby) with 13.59 cm, whereas minimum fruit girth 10.62 cm, was observed in, D_1G_2 (0.2 m x AVTO - 1707). Maximum polar, radial diameter and fruit girth in wider spacing, is might be attributed to the genetic makeup of varieties that primarily dictate the characters and do not influenced by the environment. Similar results were obtained by Dasgan and Abak (2003) in bell peppers and Bhahadur and Singh (2005) in Tomato.

Interaction effect shows that statistically

significant variation for average fruit weight, maximum fruit weight82.06 g, was recorded in interaction effect D_4G_4 (0.5 m x Pusa ruby), followed by D_3G_4 (0.4 m x Pusa ruby) with 76.83 g, whereas minimum fruit weight 57.05 g, was observed in, D_1G_1 (0.2 m x AVTO - 1706). The similar findings of increase average fruit weight and yield per plant with wider spacing was reported by Biradar *et al.*, (2014) in capsicum, Harish and Patil (2011) and Sharma *et al.*, (2011) in tomato.

In terms of number of fruits, maximum significant number of fruits per cluster5.51 fruits, was noticed in interaction effect, D_4G_4 (0.5 m x Pusa ruby), followed by D_3G_4 (0.4 m x Pusa ruby) with 5.08 fruit, whereas minimum 3.38 fruits, was recorded in, D_2G_2 (0.3 m x AVTO - 1707).This might be due to more photosynthesis as it produces more plant height and more fruit setting at wider spacing. Similar findings have been reported by Mantur and Patil (2008), Bhattarai *et al.*, (2015) and Rajendra *et al.*, (2013) in tomato. Similarly for number of fruits per plant maximum26.62 fruits, was recorded in interaction effect D_4G_4 (0.5 m x Pusa ruby), followed by D_3G_4 (0.4 m x Pusa ruby) with 25.04 fruits, whereas minimum 17.87 fruits, was recorded in, D_1G_1 (0.2 m x AVTO - 1706). This might be due to more photosynthesis as it produces more plant height and more fruit setting at wider spacing. Similar findings have been reported by Mantur and Patil (2008), Bhattarai *et al.*, (2015) and Rajendra *et al.*, (2013) in tomato.

In fruit yield/plant maximum significant yield 2.10 kg, was noticed in interaction effect D_4G_4 (0.5 m x Pusa ruby), followed by D_3G_4 (0.4 m x Pusa ruby) with 1.90 kg, whereas minimum 1.01 kg, was recorded in, D_1G_1 (0.2 m x AVTO - 1706). Similarly in yield per plot maximum90.20 kg, was noticed in interaction effect D_1G_4(0.2 m x Pusa ruby), followed by D_1G_3(0.2 m x Arka Samrat) with 65.45 kg, whereas minimum yield per plot 30.14 kg, was observed in, D_4G_1 (0.5 m x AVTO - 1706). Similar trends in yield per hectare was noticed with maximum yield95.83 ton, was noticed in interaction effect, D_1G_4 (0.2 m x Pusa ruby), followed by D_1G_3 (0.2 m x Arka Samrat) with 69.53 ton, whereas minimum yield per hectare 32.02 ton, was observed in, D_4G_1 (0.5 m x AVTO - 1706)This might be due to wider plant spacing found effective in utilization of land, nutrients and sunlight that has resulted in good quality of fruits and yield. The results are in conformity with findings of Dasgan and Abak (2003) in sweet pepper and Mantur and Patil (2008), Campillo *et al.*, (2012), Klaring and Krumbein (2013) and Kumari *et al*., (2015) in Tomato.

Quality parameters

The data on quality parameters are given in table 1.3 it is clear from the table that all the treatment differed significantly for all quality parameters. Significantly maximum TSS5.91 ^{o}Brix, was recorded in interaction effect D_1G_3 (0.2 m x Arka Samrat), followed by D_4G_3 (0.5 m x Arka Samrat) with 5.87 ^{o}Brix, whereas minimum 4.16 ^{o}Brix, was observed in, D_1G_4 (0.2 m x Pusa ruby). Similarly in Ascorbic acid maximum 26.22 mg, was noticed in interaction effect D_4G_4 (0.5 m x Pusa ruby), followed by D_2G_4 (0.3 m x Pusa ruby) with 25.87 mg, whereas minimum 20.19 mg, was observed in, D_1G_1 (0.2 m x AVTO - 1706).

Economics (Benefit: cost ratio)

The data on Economics (Benefit: cost ratio) are given in table 1.3 it is clear from the table that all the treatment differed significantly for all in gross, net return and benefit: cost ratio. In terms of Gross Return maximum Rs. 766640.00, Net Return Rs. 647430.00 and Cost Benefit Ratio 6.49 was recorded in Interaction effect G_4D_1 (Pusa Ruby) Followed by G_3D_1 (Arka Samrat) with Gross Return Rs.

5566240.00, Net Return Rs. 434530.00 and Cost Benefit Ratio 4.57 and minimum Gross Return Rs. 256160.00, Net Return Rs. 132450.00 and Cost Benefit Ratio 2.07 was recorded in G_1D_4 (AVTO - 1706).

From the present experimental findings it is concluded that the genotype G_4 (Pusa Ruby) followed by G_3 (Arka Samrat) and planting density D_4 (0.5 m) followed by D_3 (0.4 m) was found suitable in terms of growth, quality and yield per plant. In terms of yield/plot and per hectare, planting density D_1 (0.2 m) was best due to more number of plants per plot and per hectare area. In terms of economics maximum gross, net return and cost benefit ratio was recorded in genotype G_4 (Pusa Ruby) and minimum in G_1 (AVTO - 1706).

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