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Evaluation of Tomato (*Solanum lycopersicum L.*) Genotypes for Morphological, Qualitative and Biochemical Traits for Protected Cultivation

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Authors' contributions

This work was carried out in collaboration among all authors. Author AS conducted the trial, collected the data, performed the statistical analysis and wrote the first draft of the manuscript. Author PS designed the study and managed the analyses of the study. Authors AB and RK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Fourteen genotypes of tomato collected from different sources were evaluated inside naturally ventilated polyhouse at Polyhouse Complex, Department of Horticulture (Vegetable and floriculture), BAU, Sabour, Bhagalpur during 2018-2019. The experiment was laid out in RBD with three replications. Data from analysis of variance depicted that mean sum of squares of all genotypes were highly significant for all traits under study except titratable acidity and β-carotene which indicated the existence of ample genetic variability among the genotypes. Genotype NS 4266 had least days to first flowering, days fifty percent flowering, lowest number of locules, highest plant height at 60 DAT along with maximum β- carotene & lycopene content; TODINDVAR-8 had lowest number of nodes to first flower and maximum average fruit weight; Palam Tomato Hybrid-1 displayed maximum no. of flower per truss; Heemshikhar had lowest no. of days to first fruiting; TODINDVAR-5 had highest no. of fruit per truss; Arka Abha showed earliest days to first picking; San Marzano had maximum polar diameter and plant height at final stage of harvesting; TODINDVAR-6 show maximum equatorial diameter and lowest titratable acidity; Arka Samrat had

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maximum pericarp thickness; Hawaii 7998 was observed with maximum no. of fruit per plant; Arka Vikas had maximum TSS content. However, Pant Polyhouse Tomato-2 contained maximum ascorbic acid. Different types of fruit shapes viz. flat round, oval, round, heart shaped, cylindrical and fruit colour viz. red, pink, yellow-orange was exhibited by various genotypes. All the genotype displayed the absence of green shoulder on fruit except San Marzano. Three genotypes namely Palam Tomato Hybrid-1 (5.72 kg/plant), Heemshikhar (4.85 kg/plant) and NS 4266 (4.82 kg/plant) was identified for higher yield among all the genotypes.

Keywords: Tomato; polyhouse; yield; fruit shape and fruit colour.

1. INTRODUCTION

Tomato (*Solanum lycopersicum L.*; 2n=24) is an important member of family solanaceae and originated in wild form in central and South America [1]. It is primarily autogamous crop but some percent of cross-pollination also exist. Tomato is commonly treated as "Protective Food" [2], as it contain high amounts of several nutritive compounds especially carotenoids such as lycopene and β carotene (provitamin A), flavonoids, phenolic acids and ascorbic acid and minerals like calcium, iron and phosphorus.

Tomato has huge demand in markets round the year but in the main season arrival of huge quantity of produce causes occurrence of glut situation and scarcity during lean periods causing an impractical increase in price. In open field condition, round the year production is not possible because it is susceptible to several stresses. Thus to overcome these conditions, cultivation of tomato under protected cultivation is the best substitute. Protected cultivation aid to create favourable micro-climate near the crop and also help to achieve independence of weather and enables the farmers to fetches the higher earnings per unit area with additional benefit like earlier maturity, increase yield, better quality, reduced diseases and pest infestation, increase crop growth period causing longer harvesting duration which ensure off-season supply of produce. In polyhouse, generally indeterminate tomatoes are preferred due to their innate capacity of growing for longer period and utilize vertical space inside the polyhouse. Identification of indeterminate type tomato plant having higher yield, quality, desirable shape, size and colour is necessary to meet up growing demand of consumers. So there is a need for genetic improvement and to identify promising indeterminate tomato varieties that suit to particular agro-climatic conditions for protected cultivation.

2. MATERIALS AND METHODS

The experiment was carried out during October 2018 to May 2019 at Polyhouse complex, Deptt. of Horti. (Veg. and Flori.), Bihar Agricultural College, Sabour, Bhagalpur which is located at above mean sea level of 45.57 meter with 25°15'40'' N latitude and 87°2'42'' E longitude. Fourteen genotypes of tomato collected from different sources. Seedlings of indeterminate tomato hybrid were transplanted at 25th Oct. 2018 under naturally ventilated polyhouse of an area 550 m^2 at spacing of 60 x 60 cm in randomized block design with three replications. The observations were recorded for morphological trait such as days to first flowering (DFF), node to first flowering (NNFF), days to 50% flowering (DFPF), plant height at 60 DAT (PH), no. of flowers per truss (NFT), days to first fruiting (DTFF), no. of fruit per truss (NFPT), days taken to first picking (DFP), polar diameter of fruit (PD), equatorial diameter of fruit (ED), pericarp thickness (PT), no. of locules per fruit (NL), no. of fruit per plant (NFPP), average weight of fruit (AFW), fruit yield per plant (YPP), final plant height (FPH); for qualitative traits like fruit shape, fruit colour at maturity, presence of colour on shoulder of fruit; and for biochemical parameter like Total Soluble Solid (TSS), titratable acidity (TA), ascorbic acid (AA), lycopene (LY), β- carotene (BC). All mean values of the data taken randomly for each trait from five different plants from each treatment from all replications was used for further statistical study. Analysis of variance was analyzed as suggested by Panse and Sukhatme [3]. Titratable acidity was estimated as described by Ranganna [4]; ascorbic acid was estimated by the method of A.O.A.C [5]; lycopene and β- Carotene was estimated by the method of Sadashivam and Manickam [6].

3. RESULTS AND DISCUSSION

Data from analysis of variance shown that mean sum of squares of all genotypes were significant

for days to first flowering, node to first flowering, days to 50% flowering, no. of flowers per truss, days to first fruiting, no. of fruit per truss, days taken to first picking, polar diameter of fruit, equatorial diameter of fruit, pericarp thickness, no. of locules per fruit, no. of fruit per plant, average weight of fruit, fruit yield per plant, plant height at 60 DAT, final plant height, fruit shape, fruit colour at maturity, presence of colour on shoulder of fruit, TSS, ascorbic acid and lycopene except titratable acidity and β-carotene which indicate the ample of genetic variability exists in the genotypes. Thus, there is abundant scope for selection of promising genotypes. Analogous finding were also reported by Hasan et al. [7], Kumar et al. [8] and Panchbhaiya et al. [9].

3.1 Morphological Traits

Mean performance of morphological traits for fourteen genotypes of tomato are presented in Tables 1 and 2.

The mean performance studied of different genotypes shows that the genotype NS 4266 (26.60 days) was earliest days to first flowering while Hawaii 7998 (43.40 days) took maximum days. The genotype Heemshikhar (28.00 days), Palam Tomato Hybrid-1(28.07 days), Palam Pink (29.41 days) and TODINDVAR-6 (30.20 days) was statistically at par with NS 4266. Sharma & Singh [10] found parallel variation in days to first flowering. Early flowering might be due to inherent genetic potential, better growing conditions inside the polyhouse which may triggered the hormonal action of plant for production of flower forming hormone.

Lowest node to first inflorescence was recorded in genotype TODINDVAR-8 (7.60) whereas Hawaii 7998 (11.40) had highest number of node to first inflorescence. Lekshmi and Celine [11] reported no. of node to first flowering ranged 9.93 to 14.33. Dhyani et al. [12] observed average value for no. of node to first flowering ranged from 4.33-11.03. Lowest node to first inflorescence reflected that the plants may produce a large number of flowers all of them may not bear fruits.

NS 4266 (30.13 days) registered earliest days to 50% flowering followed by Palam Pink, Palam Tomato Hybrid-1 and Heemshikhar while genotype Hawaii 7998 (47.47 days) took maximum days for 50% flowering. Same deviation had found by Prema et al. [13]. Earliest days to 50% flowering were might be due to genetic makeup of genotypes and favourable growing conditions inside the polyhouse.

Maximum no. of flower per truss was recorded in Palam Tomato Hybrid-1 (9.27) followed by TODINDVAR-5 and NS 4266. Genotype TODINDVAR-6 (4.47) showed lowest number of flowers per truss. Similar variation reported by Cheema et al. [14]. These variations might be due to environmental conditions inside the polyhouse and genetic potential of genotypes.

Table 1. Mean performance of morphological traits for fourteen genotypes of tomato

Genotypes	DFF	NFF	DFPF	NFT	DTFF	NFPT	PH (cm)	DFP
TODINDVAR-6	30.20	11.28	35.40	4.47	45.00	2.67	136.27	116.63
TODINDVAR-5	39.67	9.40	45.73	9.20	64.80	5.80	163.80	126.53
TODINDVAR-8	41.80	7.60	45.00	5.70	69.45	1.67	116.40	135.10
Pant Polyhouse Tomato-2	37.93	10.00	42.87	4.90	49.33	3.97	106.67	115.13
NS 4266	26.60	8.33	30.13	8.93	42.47	4.13	169.80	119.00
Palam Tomato Hybrid-1	28.07	8.93	32.27	9.27	46.07	4.47	149.33	112.73
Arka Abha	37.67	9.67	42.27	4.93	49.87	3.67	107.60	111.67
Arka Samrat	36.40	9.87	41.87	7.13	50.93	3.80	119.80	120.73
Arka Vikas	33.87	10.00	38.40	5.93	55.00	2.73	122.13	117.93
Hawaii 7998	43.40	11.40	47.47	7.07	58.93	2.93	126.60	120.67
Arka Rakshak	38.13	9.67	43.87	6.73	55.80	2.80	122.47	124.27
San Mrazano	31.60	9.33	35.20	5.20	53.67	2.20	101.87	124.60
Heemshikhar	28.00	8.20	32.00	7.33	41.47	4.60	160.33	118.47
Palam Pink	29.41	8.30	31.00	7.50	43.67	2.85	103.76	112.02
S. Em. ±	1.299	0.336	1.409	0.228	1.368	0.124	4.615	3.532
C. D. at 5%	3.78	0.98	4.10	0.66	3.98	0.36	13.42	10.27
C. V. %	6.52	6.17	6.28	5.85	4.57	6.23	6.19	5.11

Table 2. Mean performance of twenty one characters for fourteen genotypes of tomato

Genotypes	NL	PD (cm)	ED (cm)	PT (mm)	FPH (cm)	AFW (g)	NFPP	YPP (kg/plant)
TODINDVAR-6	4.13	4.46	5.73	3.14	232.33	78.27	44.00	3.02
TODINDVAR-5	2.07	5.26	4.80	5.32	372.67	54.80	52.33	3.17
TODINDVAR-8	5.20	4.78	4.85	5.47	300.33	99.73	25.28	2.14
Pant Polyhouse Tomato-2	2.00	4.26	4.38	4.55	384.67	66.80	60.00	3.30
NS 4266	2.00	4.53	5.36	5.23	360.20	80.13	70.27	4.82
Palam Tomato Hybrid-1	3.07	4.18	4.53	3.98	377.53	60.33	101.00	5.72
Arka Abha	3.47	4.29	4.84	3.95	219.07	73.33	55.33	3.10
Arka Samrat	3.13	5.07	5.38	5.76	255.40	97.07	47.53	4.12
Arka Vikas	4.00	3.22	4.36	3.28	342.33	49.20	42.20	2.21
Hawaii 7998	2.33	3.51	4.01	4.03	390.67	32.40	101.87	3.29
Arka Rakshak	2.40	4.84	4.36	5.02	263.13	68.07	66.60	4.06
San Mrazano	2.00	6.46	3.43	3.81	417.53	49.18	34.07	2.22
Heemshikhar	2.00	4.32	5.09	5.38	361.67	64.47	63.40	4.85
Palam Pink	3.50	4.52	4.02	4.07	228.47	80.33	26.80	1.92
S. Em. $\pm$	0.107	0.179	0.150	0.209	8.410	2.368	2.342	0.119
C. D. at 5%	0.31	0.52	0.44	0.61	24.45	6.88	6.18	0.35
C. V. %	6.27	6.82	5.60	8.06	4.53	6.02	7.18	6.04

Earliest days to first fruiting was observed for Heemshikhar (41.47 days) followed by NS 4266, Palam Pink and TODINDVAR-6 whereas maximum days to first fruiting were observed in TODINDVAR-8 (69.45 days). The same result was also obtained by Pandey et al. [15]. Days to first flowering and days to first fruiting is important for getting fruit earlier and thus fetches higher price from the market.

The genotypes TODINDVAR-5 (5.80) exhibited maximum no. of fruits/ truss whereas minimum number of fruits per truss (1.67) was recorded in TODINDVAR-8. Variation in no. of fruits per truss may be due to interaction between genetic factors and the environmental conditions like temperature, light, humidity other climatic factors existing inside the polyhouse during the growing period.

For the character days taken to first fruit picking was earliest in Arka Abha (111.67 days). The genotype TODINDVAR-8 was recorded maximum days to first fruit picking i.e. 135.10 days. Early picking was might be due to genetic makeup of genotypes and favourable growing conditions inside the polyhouse.

The mean performance of number of locules was recorded 2.00 for genotypes Pant Polyhouse Tomato-2, NS 4266, San Mrazano and Heemshikhar. The maximum number of locules was recorded for genotype TODINDVAR-8 (5.20). Similar deviation was seen by Dar et al. [16] and Dhyani et al. [12]. For seed production and table purpose higher number of locules/ fruit is preferred whereas, for processing purpose lower number of locules/fruit is ideal.

San Mrazano was having the highest polar diameter (6.46 cm) after that TODINDVAR-5 while Arka Vikas was having the lowest polar diameter (3.22 cm). Variation in mean value for the fruit length was 3.50 cm to 11.33 cm reported by Dhyani et al. [12].

The equatorial diameter was lower for San Mrazano (3.43 cm) while higher for TODINDVAR-6 (5.73 cm). Genotype NS 4266 and Arka Samrat were statistically at par with TODINDVAR-6. Sharma & Singh [10] also noted analogous deviation for equatorial diameter of fruit. Variation in fruit shape was might be due to genetic makeup of the genotypes.

Arka Samrat showed higher pericarp thickness (5.76 mm) whereas lower pericarp thickness was recorded in TODINDVAR-6 (3.14). For long distance transportation and post harvest handling, thick pericarp is preferred. Thick pericarp is suitable for canning and long distance transport. Similar deviation was also noted for pericarp thickness by Sharma & Singh [10] and Dhyani et al. [12].

Plant height at 60 DAT was higher in NS 4266 (169.80 cm) followed by TODINDVAR-5 and Heemshikhar whereas plant height at final harvest was maximum in San Mrazano (417.53 cm) followed by Hawaii 7998 (390.67 cm). In

polyhouse, plant received lower light intensity which may help in cell elongation and intermodal length which lead to increased plant height. It may also due to vertically trained plant which help in gaining height and have better aeration.

The maximum average fruit weight was recorded in genotype TODINDVAR-8 (99.73 g) after that genotype Arka Samrat and TODINDVAR-8 whereas, minimum average fruit weight in genotype Hawaii 7998 (32.40 g). Dhyani et al. [12] reported average fruit weight from 62.50 g to 106.74 g; Cheema et al. [14] from 30.00 g to 52.50 g. Fruit weight is inversely related with no. of fruits/plant although both of these traits are principal yield attributing traits. Deviation in average fruit weight might be due to interaction between genetic factor and environmental conditions exist during flowering, fruit-set, fruit growth and development.

The genotype Hawaii 7998 (101.87) had higher number of fruit per plant and Palam Tomato Hybrid-1was statistically at par with Hawaii 7998 whereas lower value (25.28) of no of fruits/plant was observed in TODINDVAR-8. Increased or decreased in size and weight of fruits influenced no. of fruits/ plant. Small sized fruits and early fruiting may tends to produce larger no. of fruits per plant.

The utmost fruit yield/plant was obtained from Palam Tomato Hybrid-1 (5.72 Kg/ plant) after that Heemshikhar (4.85), NS 4266 (4.82) and Arka Samrat (4.06). Fruit yield/plant is depending upon several yield contributing traits like number of fruit per plant, average fruit weight, no. of flower per truss and no. of fruit/truss etc. The environment inside the polyhouse favour early flowering which resulted in early fruit-set and thereby increased fruit yield per plant. Dhyani et al. [12] reported similar deviation in fruit yield/plant.

3.2 Biochemical Parameters

Mean performance of biochemical traits for fourteen genotypes of tomato are presented in Table 3.

Arka Vikas (5.29^{o}Brix) shows higher total soluble solid value whereas lower TSS 3.33^{o}Brix found in genotype Palam Pink. Higher TSS is preferred for processing. Analogous variation in TSS was also seen by Sharma and Singh [10]. Inherent genetic makeup plays a chief role in controlling TSS content of fruits.

The lower value of titratable acidity was found in TODINDVAR-6 (0.35 mg/100 g) and higher value found in Pant Polyhouse Tomato-2 (1.20 mg/100 g). Similar variation in titratable acidity was reported by Caliman et al. [17] and Dhyani et al. [18].

For the character ascorbic acid, higher value was found in Pant Polyhouse Tomato-2 (35.19 mg/ 100 g) followed by Arka Rakshak (33.99 mg/ 100 g) and San Mrazano (33.42 mg/ 100 g) while, genotype Hawaii 7998 (16.86 mg/ 100 g) was recorded lower value for ascorbic acid.

Table 3. Mean performance of biochemical traits for fourteen genotypes of tomato

Genotypes	TSS (^{o}Brix)	TA (%)	AA (mg/100 g)	BC (mg/100 g)	LY (mg/100 g)
TODINDVAR-6	4.15	0.35	26.49	0.45	1.35
TODINDVAR-5	4.64	0.38	21.82	0.14	0.16
TODINDVAR-8	4.42	0.92	18.84	0.32	0.99
Pant Polyhouse Tomato-2	4.21	1.20	35.19	0.85	2.64
NS 4266	3.54	0.54	23.08	1.33	4.11
Palam Tomato Hybrid-1	4.34	0.55	17.73	1.11	3.41
Arka Abha	4.77	0.94	23.91	0.64	1.93
Arka Samrat	4.08	0.64	23.55	0.35	1.07
Arka Vikas	5.29	1.04	30.01	0.80	2.41
Hawaii 7998	4.91	0.77	16.68	0.57	1.73
Arka Rakshak	4.85	0.68	33.99	0.47	1.43
San Mrazano	4.65	0.75	33.42	0.80	2.48
Heemshikhar	3.38	0.51	17.05	0.70	1.75
Palam Pink	3.33	0.40	16.68	0.59	1.67
S. Em. $\pm$	0.068	0.011	0.328	0.013	0.030
C. D. at 5%	0.20	0.03	0.95	0.04	0.09
C. V. %	2.72	2.74	2.35	3.44	2.64

Table 4.Qualitative traits of tomato genotypes

Genotypes	Fruit colour	Fruit shape	Presence of green shoulder on fruit
TODINDVAR-6	Red	Flat round	Absence
TODINDVAR-5	Yellow - Orange	Oval	Absence
TODINDVAR-8	Red	Flat round	Absence
Pant Polyhouse Tomato-2	Red	Round	Absence
NS 4266	Red	Heart shaped	Absence
Palam Tomato Hybrid-1	Red	Round	Absence
Arka Abha	Red	Round	Absence
Arka Samrat	Red	Round	Absence
Arka Vikas	Red	Flat round	Absence
Hawaii 7998	Red	Round	Absence
Arka Rakshak	Red	Oval	Absence
San Mrazano	Red	Cylindrical	Presence
Heemshikhar	Red	Flat round	Absence
Palam Pink	Pink	Round	Absence

The genotype NS 4266 was recorded higher value (4.11 mg/ 100 g) followed by Palam Tomato Hybrid-1 and Pant Polyhouse Tomato-2 while genotype TODINDVAR-5 was recorded lower value (0.16 mg/ 100 g) for lycopene. Lycopene synthesis may be depending upon environmental factors that are temperature, humidity and light inside the greenhouse.

Genotype NS 4266 showed maximum β-carotene content (1.33 mg/ 100 g) followed by Palam Tomato Hybrid-1 and Pant Polyhouse Tomato-2 whereas least in TODINDVAR-5 (0.14 mg/ 100 g). Composition of β-carotene may be depending upon among genotypes and environments.

3.3 Qualitative Traits

Different types of fruit shape was exhibited by the genotypes (Table 4) viz. flat round shaped found in four genotypes, six genotypes show round shaped, oval shaped shown by two genotypes, each heart shaped and cylindrical shaped fruit shown by one genotype. Four types of fruit colour viz. red, pink, yellow-orange were observed in which twelve genotypes had red coloured fruits and one genotype each having pink and yellow-orange coloured fruits. All the genotype shows absence of green shoulder on fruit except San Marzano. The variation in fruit shape, fruit colour at maturity and presence of colour on shoulder of fruit among tomato hybrids was may be due to difference in their genetic behavior and environmental condition inside polyhouse.

4. CONCLUSION

On the basis findings, it can be concluded that wide range of genetic variability are exist in present set of genetic material except titratable acidity and β-carotene. Thus, there is abundant scope for selection of promising genotypes. Among the genotypes, three genotypes namely Palam Tomato Hybrid-1, Heemshikhar and NS 4266 were identified for higher yield under protected cultivation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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