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Exploring genetic variability in tomato for yield and quality traits

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Abstract
The present investigation entitled "Exploring genetic variability in tomato for yield and quality traits" was carried out at College of Horticulture, Bengaluru campus, University of Horticultural Sciences, Bagalkot in 2019-20 to evaluate 260 tomato genotypes along with four checks for 19 characters using augmented RBD design. Highly significant differences were found between 260 genotypes for each of the nineteen characteristics that were the subjected to analysis of variance. Prominent role was played by the environment for the expression of characters studied, as evidenced by the fact that estimates of Phenotypic Coefficient of Variation (PCV) were higher than that of the Genotypic Coefficient of Variation (GCV) for majority of the characters studied. The estimates of GCV and PCV were of the highest magnitude for the characters average fruit weight (49.63, 50.29) followed by fruit firmness (46.76, 47.11), lycopene content (47.85, 48.14), number of fruit cluster per plant (32.78, 33.50), fruit diameter (32.83, 33.38), pericarp thickness (32.40, 32.97), ascorbic acid content (33.72, 34.76), number of seeds per fruit (30.54, 30.81) and yield per plant (29.84, 30.42). High heritability was found for all the characters except days to harvest (53.98%). The highest heritability was recorded for the character number of fruits per cluster (99.45%) followed by lycopene content (98.78%) and fruit firmness (98.51). Genetic advance as percentage of mean was found highest in combination with high heritability for the characters average fruit weight (100.88%) followed by lycopene content (97.97%) and fruit firmness (95.60%). These traits were under the influence of additive gene effects and that they are more reliable for efficient selection.

Keywords: Tomato, variability, heritability, genetic advance

Introduction
Tomatoes are among the most commonly consumed vegetables in the world as well as one of the most important processing vegetable endowed with exceptional qualities. Despite once being thought of as a poisonous plant, tomatoes are now found on nearly all continents, and are a key ingredient in many different dishes due to their special characteristics. Tomato plants have a small genome, are self-fertile, have fewer number of genetic mutations, and are easy to breed as they are self-pollinating and homozygous (Foolad, 2007) [10].
To increase tomato productivity, genetic improvement through the development of superior varieties should be the primary consideration by utilizing the genetic variability among and within the population's genetic pool. Several factors affect the efficiency of selection, such as genetic variability, heritability which is the degree of transmissibility of desirable characteristics, and the expected gain in genetic diversity in a population. Thus, in this study different genotypes of tomato were examined for various horticultural traits to determine the genetic variability, heritability, and genetic gain.

Materials and Methods
The experimental field was located in experimental block, Department of Biotechnology, College of Horticulture, Bengaluru campus which is at an altitude of 930 m above MSL 12°58' North latitude and 77°35' East-longitude in the Eastern Dry Zone (Zone-5) of Karnataka. The field evaluation of 260 accessions was done in an Augmented Block Design with four checks, namely Arka Saurabh, Anagha, DMT-2, and DMT-4 (Table 1).

Twenty-five days old tomato seedlings were used for transplanting on raised bed with 60 cm x 45 cm spacing. Observations were made on five randomly chosen plants and the characters under study include: plant height, number of branches per plant, days to 50% flowering, number of fruit cluster per plant, number of fruits per cluster, number of days to harvest, average fruit weight, fruit length, fruit width, pericarp thickness, number of locules, number of seeds per fruit, yield per plant, fruit firmness, titratable acidity, fruit ph, lycopene content, ascorbic acid content and Total soluble solids (TSS). Based on estimates of genotypic and phenotypic variation, genotypic and phenotypic coefficients of variance were calculated in accordance with Burton and Devane (1953). The Hanson *et al.* (1956) [11] technique and Johnson *et al.* (1955) [15] procedures were used to determine the broad sense heritability and Genetic advance as percent of mean respectively.

Results and Discussion

Analysis of variance (ANOVA)

The analysis of variance for yield and contributing traits indicated that a significantly higher amount of variability existed among the genotypes for all the characters studied *viz.,* plant height, number of branches per plant, days to 50 per cent flowering, number of clusters per plant, number of fruits per cluster, number of days to harvest, average fruit weight, number of locules per fruit, fruit diameter and total yield per plant (Table 2). The genotypes under investigation had significant variations in their overall performance across all characteristics examined, suggesting that the germplasm was genetically heterogeneous.

The descriptive statistics in terms of mean, range, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (h^2), genetic advance (GA) and genetic advance over per cent of mean (GAM) were determined for various characters studied in tomato mini-core collection and results are presented in Table 3.

A wide variation was observed for plant height as the mean values for each accession ranged from 50.23 cm (Azad T-2) to 141.75 cm (EC-620411) with a grand mean of 98.64 cm. The variation for the number of branches per plant ranged from 3.00 (EC-501577 and C-3-2) to 14.20 (Feb-02) with a grand mean of 7.33. The variation observed for days to 50 per cent flowering ranged from 22.00 days (EC-2791) to 40.00 days (H-88-78-2) with an average of 32.01 days. With a grand mean of 19.55, the range for the number of clusters per plant was 8.20 (Solan Vajr) to 52.60 (IC-469626). The grand mean for the number of fruits per cluster was 4.54, with a range of 2.58 (EC-381263) to 9.23 (EC-620455). Days to first harvest varied from 47.20 (Solan Gola) to 86.60 (EC-560340), with a grand mean of 68.69. A grand mean of 39.59 g was found for the average fruit weight, which varied from 8.62 g (TLH-27) to 102.05 g (EC-620444). The fruit length varied from 1.17 (C-9-2) to 6.86 (F-6050-1), with a grand mean of 3.76, while the fruit diameter ranged from 1.21 (91/384) to 6.69 (Arka Alok), with a grand mean of 3.87. A highly significant difference was observed for pericarp thickness across the accessions. It ranged from lowest in H-88-78-1 (1.19 mm) and highest in INDAM-2103-1 (7.23 mm) with a grand mean of 4.14 mm. The range of locules per fruit spanned from 2 in EC-521039 to 6.40 in EC-501577, averaging 3.71. The observed range for the number of seeds per fruit was between 35.26 (EC-529080) and 201.50 (EC-519730), with an overall average of 107.90. A notable variation in total yield per plant was recorded, ranging from 0.74 kg (WIR-13706) to 5.20 kg (C-26-1), with an average yield of 2.78 kg. The average fruit firmness was 1.48 kg/cm², with a range of 0.61 kg/cm² in Swarna Naveen to 3.67 kg/cm² in INDAM-2103-6-4. Among the genotypes studied, the highest and lowest values for titratable acidity were 0.23 (NDT-1) and 1.06 (G-4-5) respectively. The mean obtained was 0.51. The observed range for fruit pH spanned from 3.84 (EC-538419) to 4.78 (PDVT-14), averaging 4.26. The results on the performances for lycopene content indicated that the genotype G-6-3 (0.83) had the lowest mean value and the genotype Utkal Urvashi (19.28 mg/100g fruit weight) had the highest value. The mean for the genotypes were found to be 8.27 mg/100g fruit weight. For ascorbic acid content, the variation ranged from 4.16 (EC-538419) to 35.15 (C-11-1) with a grand mean of 16.71. The variation observed for Total soluble solids ranged from 1.54 (Nandhi) to 8.49 (F-6022) with an overall mean of 4.71 ^{o}Brix.

Greater role was played by the environment for the expression of characters studied, as evidenced by the fact that estimates of Phenotypic Coefficient of Variation (PCV) were higher than that of the Genotypic Coefficient of Variation (GCV) for the majority of the characters studied. The estimates of GCV and PCV were of the highest magnitude for the characters average fruit weight (49.63, 50.29), fruit firmness (46.76, 47.11), lycopene content (47.85, 48.14), number of fruit cluster per plant (32.78, 33.50), fruit diameter (32.83, 33.38), pericarp thickness (32.40, 32.97), ascorbic acid content (33.72, 34.76), number of seeds per fruit (30.54, 30.81) and yield per plant (29.84, 30.42). Corroborating results were obtained for the characters fruit weight (Rai *et al.,* 2016; Manish *et al.,* 2017; Aralikatti *et al.,* 2018) [24, 20, 1] fruit firmness (Khuntia *et al.,* 2019; Mukherjee *et al.,* 2020) [16, 21], lycopene content (Sunilkumar *et al.,* 2016; Raut *et al.,* 2021) [30, 25], number of fruit cluster per plant (Ismaeel *et al.,* 2019; Raut *et al.,* 2021) [25, 14], Fruit diameter (Nwosu *et al.,* 2018) [22], pericarp thickness (Shweta *et al.,* 2016; Hussain *et al.,* 2021) [27], number of seeds per fruit (Doddamani *et al.,* 2017; Venkadeswaran *et al.,* 2020) [8] and yield per plant (Das *et al.,* 2018; Shah *et al.,* 2022) [7, 26].

Moderate GCV and PCV were identified in plant height (16.51, 17.88), number of locules per fruit (16.37, 17.97). Similar results were published for plant height (Somraj *et al.,* 2017; Basfore *et al.,* 2020) [29, 3] and number of locules per fruit (Bajpai *et al.,* 2018; Basfore *et al.,* 2020) [2, 3]. Low GCV and PCV was found for the character fruit pH (4.32, 4.37) which corroborated with the results of Mahebub *et al.* (2021) [19] and Pooja *et al.* (2022) [23]. Low GCV but moderate PCV were found for the characters days to 50% flowering (9.28, 10.51) and number of days to harvest (7.59, 10.32). Similar results were reported by Bhandari *et al.,* 2017 [4].

Differences observed between GCV and PCV were of lesser magnitude for most of the characters studied. GCV and PCV differences were highest for the characters *viz.,* fruit length (30.47, 33.24), days to harvest (7.59, 10.32), plant height (16.51, 17.88) and number of locules per fruit (16.37, 17.97). Similar findings were reported by Rai *et al.,* 2016 [24]; Somraj *et al.,* 2017 [29]; Khuntia *et al.,* 2019 [16]; Mukherjee *et al.,* 2020 [21] and Hussain *et al.,* 2021 [13].

High heritability was found for all the characters except days to harvest (53.98%). The highest heritability was recorded for the character number of fruits per cluster (99.45%) followed by lycopene content (98.78%) and fruit firmness (98.51). Genetic advance as percentage of mean was found highest in combination with high heritability for the characters average fruit weight (100.88%) followed by lycopene content (97.97%), fruit firmness (95.60%). Similar results were observed by Singh and Janeja, 2018 [28]; Ismaeel *et al.,* 2019 [14]; Mukherjee *et al.,* 2020 [21]. The amount of genetic advance that can be achieved

depends on the heritability of the trait being selected for, the intensity of selection, and the genetic variability within the population (Charlesworth and Charlesworth, 2010) [6]. High heritability combined with moderate GAM was found for days to 50% flowering (16.89%), days to harvest (11.48%). Similar results were obtained for days to 50% flowering (Hasan *et al.*, 2016; Sunilkumar *et al.*, 2016) [12, 30] and days to harvest (Kumar *et al.*, 2020; Eppakayala *et al.*, 2021) [9]. Lowest GAM was found for the character fruit pH (8.78%) which was supported by the finding of Singh *et al.*, 2018.

Table 1: List of Tomato accessions used in the study

SL No.	Accession	SL No.	Accession	SL No.	Accession	SL No.	Accession
1	Ageta-32	38	DARL-66	75	EC-538380	112	EC-620455
2	Angoorlata	39	Dhrubya	76	Ec-538404	113	EC-620456
3	Arkaabha	40	DT-10	77	EC-538405	114	EC-620464
4	Arkaalok	41	DVRT-1	78	EC-538408	115	EC-620469
5	ArkaMeghalli	42	DVRT-2	79	EC-538419	116	EC-620470
6	Arkavikas	43	E-4-3	80	EC-538423	117	EC-620474
7	Avinash-2-2-1	44	EC-2791	81	EC-538439	118	EC-620476
8	Azad T-2	45	EC-13904	82	EC-538440	119	EC-620480
9	Azad T-5	46	EC-317-6-1	83	EC-538441	120	EC-620486
10	B-4-1	47	EC-273966	84	EC-538455	121	EC-620500
11	B-7-2	48	EC-381263	85	EC-552141	122	EC-620502
12	Bhillai	49	EC-381554	86	EC-560340	123	EC-620514
13	BL-1208	50	EC-501574	87	Ec-570028	124	EC-620519
14	BTH-9 Male	51	EC-501575	88	EC-605694	125	Ec-620530
15	C-1-4	52	EC-501576	89	EC-605695	126	Ec-620533
16	C-3-2	53	EC-501577	90	EC-605696	127	Ec-620540
17	C-4-1	54	EC-501580	91	Ec-620362	128	Ec-620556
18	C-8-1	55	EC-501582	92	EC-620366	129	Ec-620568
19	C-9-2	56	EC-501583	93	EC-620370	130	Ec-620575
20	C-10-2	57	EC-519730	94	EC-620373	131	Ec-620598
21	C-11-1	58	EC-520046	95	EC-620374	132	Ec-625644
22	C-11-2	59	EC-520059	96	EC-620375	133	Ec-625645
23	C-11-3	60	EC-520061	97	EC-620383	134	Ec-625651
24	C-20-1	61	EC-520071	98	EC-620386	135	Ec-625652
25	C-20-2	62	EC-520074	99	EC-620398	136	Ec-625660
26	C-26-1	63	EC-520075	100	EC-620401	137	EC-6202041
27	CHRT-4	64	Ec-520078	101	EC-620403	138	F-5020
28	CH-155	65	Ec-521039	102	EC-620406	139	F-6022
29	C0-3	66	Ec-521056	103	EC-620409	140	F-6050-1
30	CLN-2026	67	Ec-521078	104	EC-620410	141	F-6059
31	CLN-2116	68	Ec-526139	105	EC-620411	142	F-7012
32	CLN-1621	69	EC-528372	106	EC-620413	143	F-7025
33	CLN-2366	70	EC-528374	107	EC-620419	144	F-7028
34	D-1-1	71	Ec-529080	108	EC-620421	145	F-6009
35	D-2-2-1	72	Ec-529083	109	EC-620438	146	FEB.-02
36	D-3-2	73	EC-538138	110	EC-620444	147	FEB.-04
37	D-5-1	74	Ec-538155	111	EC-620446	148	FLA-7171
149	FLA-7421	176	INDAM-2103-1-1	203	NDT-4	230	Solanvajr
150	FLORA-DADE	177	Indam-2103-4	204	NDTVR-60	231	Sun-cherry
151	G-4-5	178	INDAM-2103-6	205	NDTVR-73	232	Swarna Naveen
152	G-5-4	179	INDAM-2103-6-1	206	NF37SB-8	233	Swarnavaibhav
153	G-6-3	180	INDAM-2103-6-4	207	Palam Pink	234	TLBR-6
154	GT-1	181	jawahar-99	208	Pant T-3	235	TLH-17
155	GT-2	182	kashiHemant	209	pant T-5	236	TLH-27
156	GT-3	183	KashiSharad	210	Parul	237	TLH-30
157	H-88-78-1	184	KashiVishesh	211	Pb-Chhuhara	238	Tripura local
158	H-88-78-2	185	Kashiamrit	212	Pb.Upma	239	UtkalPragyan
159	H-88-78-3	186	KashiAnupam	213	Persia Bed	240	Utkal raja
160	H-88-78-4	187	Kajla	214	PDT-3-1	241	VRT-32-1
161	H-88-78-5	188	Kalyanpur type-1	215	PDVT-14	242	VRT-101A
162	Hawai	189	Kashmiriya	216	PKM-1	243	WIR-3957
163	HiasrAnmol	190	LA-3772	217	PS-1	244	WIR-5032
164	HisarArun (Sel-7)	191	LA-3957	218	Prestige	245	WIR-13706
165	Hisarlalit	192	LA-3997	219	PusaGaurav	246	WIR-13708
166	I-4-4	193	M-1-4	220	Pusa Ruby	247	97/384
167	IC-373378	193	M-3-2	221	Pusa-120	248	97/753
168	IC-427766	195	MUKTHI	222	Punjab Barkha Bahar-2	249	97/754 (Kewalo)
169	IC-447708	196	Money Maker	223	Pusa Hybrid-2	250	15 SB
170	IC-469626	197	Monte Favet	224	Roma	251	Rio Grande

171	IIHR-01	198	N-2-2	225	sanjeevani	252	S.Lalima
172	IIHR-2202	199	N-2-3	226	Sankranti	253	Swezerland
173	INDAM-2102	200	Nandhi	227	Sel-18	254	UtkalUrvashi
174	INDAM-2103	201	NDT-1	228	Sioux	255	WIR-13717
175	INDAM-2103-1	202	NDT-8	229	SolanGola	256	Pallavi
257	Punjab Keshri	258	V. Pragyan	259	DMT1	260	DMT3

Table 2: Analysis of variance (ANOVA) for yield and quality traits in tomato

Augmented R.B.D. ANOVA (Summary)																			
Source of variation	**DF**	**Plant height**	**Number of branches plant**	**Days to 50 % flowering**	**No of clusters per plant**	**Fruits per cluster**	**Days to Harvest**	**Average fruit weight**	**Fruit Length**	**Fruit width**	**Pericarp Thickness**	**Number of locules per fruit**	**No. of Seeds per fruit**	**Yield per plant**	**Fruit firmness**	**Titratable acidity**	**Fruit pH**	**Lycopene content**	**Ascorbic Acid**	**TSS**
Blocks	4	1119.572 **	1.322 *	3.626	332.625 **	10.371 **	107.302 *	2282.777 **	5.621 **	5.061 **	4.354 **	0.659 **	11004.940 **	1.105 **	0.839 **	0.052 **	0.065 **	4.407 **	23.705 **	1.689 **
Treatments	263	346.033 **	4.918 **	12.374 **	41.713 **	1.281 **	53.35	422.819 **	1.630 **	1.787 **	1.907 **	0.483 **	1044.644 **	0.759 **	0.498 **	0.023 **	0.037 **	16.762 **	39.068 **	1.110 **
Checks	3	1887.996 **	11.353 **	37.438 **	11.728 *	0.404 **	51.854 *	1147.945 **	1.076 *	4.487 **	0.551 **	2.837 **	1127.432 **	2.572 **	0.132 **	0.050 **	0.206 **	25.960 **	159.479 **	0.473 **
Varieties	259	324.371 **	4.644 **	11.753 **	44.936 **	1.371 **	51.638 *	415.755 **	1.625 **	1.753 **	1.95 **	0.464 **	1159.559 **	0.747 **	0.513 **	0.023 **	0.036 **	16.632 **	35.336 **	1.113 **
Checks vs. Varieties	1	4348.086 **	60.188 **	39.425 **	293.054 **	11.584 **	773.228 **	6922.442 **	21.392 **	17.608 **	7.213 **	0.287	3860.410 **	1.425 **	0.232 **	0.026 **	0.001	36.196 **	706.087 **	6.598 **
Error	12	45.843	0.271	2.487	1.831	0.007	23.135	10.371	0.249	0.055	0.064	0.075	19.074	0.027	0.007	0.001	0.001	0.193	1.974	0.045

Table 3: Genetic variability parameters for yield and quality traits in tomato

Sl. No.	Trait	Range		Grand Mean	Variance		Co-efficient of variability		h^2 (Broad Sense)	GA	GAM
		Min	Max		GV	PV	GCV (%)	PCV (%)			
1	Plant height (cm)	50.23	144.95	98.64	265.22	311.06	16.51	17.88	85.26	30.98	31.40
2	Number of Branches	3.00	14.20	7.33	4.17	4.44	27.85	28.74	93.90	4.07	55.60
3	Days to 50% flowering	22.00	40.00	32.01	8.82	11.31	9.28	10.51	78.01	5.41	16.89
4	Number of fruit cluster per plant	8.20	52.60	19.55	41.05	42.88	32.78	33.50	95.73	12.91	66.06
5	Number of fruits per cluster	2.58	9.23	4.54	1.30	1.31	25.10	25.17	99.45	2.34	51.57
6	Days to harvest	47.20	86.60	68.69	27.14	50.28	7.59	10.32	53.98	7.89	11.48
7	Average fruit weight	8.62	102.05	39.59	386.01	396.38	49.63	50.29	97.38	39.94	100.88
8	Fruit length (cm)	1.17	6.86	3.76	1.31	1.56	30.47	33.24	84.02	2.16	57.53
9	Fruit diameter	1.21	6.69	3.87	1.62	1.67	32.83	33.38	96.73	2.58	66.51
10	Pericarp thickness	1.19	7.23	4.14	1.80	1.86	32.40	32.97	96.57	2.71	65.58
11	Number of locules	2.00	6.40	3.71	0.37	0.45	16.37	17.97	83.05	1.14	30.74
12	Number of seeds per fruit	35.26	201.50	107.90	1085.98	1105.05	30.54	30.81	98.27	67.30	62.37
13	Yield per plant	0.74	5.20	2.78	0.69	0.71	29.84	30.42	96.20	1.67	60.28
14	Fruit firmness	0.61	3.65	1.48	0.48	0.49	46.76	47.11	98.51	1.42	95.60
15	Titratable acidity	0.23	1.06	0.51	0.02	0.02	28.22	28.98	94.86	0.29	56.62
16	Fruit pH	3.84	4.78	4.26	0.03	0.04	4.32	4.37	97.50	0.37	8.78
17	Lycopene Content	0.83	19.28	8.18	15.65	15.85	47.85	48.14	98.78	8.10	97.97
18	Ascorbic Acid Content	4.16	35.15	16.71	31.77	33.74	33.72	34.76	94.15	11.27	67.41
19	Total Soluble Solids	1.54	8.49	4.71	1.02	1.06	21.38	21.85	95.74	2.03	43.10

GV= Genotypic variance GCV= Genotypic Coefficient of variance h^2= Heritability in broad sense
PV= Phenotypic variance PCV= Phenotypic Coefficient of variance
GA= Genetic advance GAM= Genetic advance as percentage of mean

Conclusion

The findings of this investigation indicate that a sufficient amount of genetic variability was measured for different traits in diverse genotypes of tomato, suggesting that selection and hybridization are significant factors for improving the genotypes for these traits. A notable variation in total yield per plant was recorded with a mean yield of 2.78. High per cent PCV (30.42%) and GCV (29.83%) along with high heritability (96.20%) and expected genetic advance as per cent mean (60.28%) were observed for this trait. Due to the additive gene playing a predominant role in genetic gain, the magnitude of heritability and genetic gain are proportionate, making them more reliable for effective selection. Moreover, moderate to high GCV was found with moderate to high heritability as well as genetic advance as percentage of mean for many characters under study, indicating predominant additive gene action and these traits have ample scope for selection to improve these traits.

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