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Studies on morphological and Physio-chemical characterization of different tomato genotypes

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Abstract
The present study on morphological and Physio-chemical characteristics of four crosses and seven genotypes of tomato were carried out during kharif 2021 at Western Block Farm, Horticultural College and Research Institute, Periyakulam of Theni District, Tamil Nadu. The experiment was carried out with three replications in Randomized Block Design. The aim of this study was to identify the tomato genotypes with superior morphological (fruit shape, fruit colour, fruit length (cm), fruit width (cm), average fruit weight (g), pericarp thickness (mm), number of locules per fruit) and Physio-chemical characteristics (fruit firmness (kg/cm^2), total soluble solids (°Brix), ascorbic acid content (mg per 100 g) and titrable acidity (%). The derivative of cross Acc. 14 × Acc. 71 recorded the highest average fruit weight (69.53g), fruit firmness (2.27 kg/cm^2) and pericarp thickness (5.44 mm), while that of Acc. 14 × PKM-1 was found to possess the highest number of locules per fruit (6.30). The cross PKM-1 × Acc. 90 exhibited the highest fruit width (5.13 cm) and total soluble solids (5.40°Brix). The highest ascorbic acid content was found in COTH 3 (37.08 mg per 100 g). With respect to titrable acidity, PKM-1, which is one of the parents recorded that the highest titrable acidity (0.87%).

Keywords: Tomato, quality, fruit firmness, total soluble solids, ascorbic acid, acidity

Introduction
Tomato (*Solanum lycopersicum* L.) is the most important colourful versatile solanaceous fruit vegetable with chromosome number of 2n = 2x = 24. It is believed to be originated from South America (Ali *et al.*, 2012) [3] and is an annual herbaceous vegetable popularly called as “love apple” and extensively cultivated throughout the world. Ripe fruits are eaten raw as salads and processed forms as sauces, ketchup, powder, paste, puree, soup and canned fruits. Green unripe fruits are used to manufacture pickles and chutney (Sureshkumara *et al.*, 2017) [25]. It is a bisexual self-pollinated day neutral and warm season vegetable crop. It has the richest source of antioxidants, Vitamin C, Vitamin A and minerals (Ca, P, Fe) in diet (Sowjanya and Sridevi, 2020) [23].

After China, India is second in tomato cultivation and fourth in terms of geography (Pugalendhi *et al.*, 2020) [19]. Tomatoes are cultivated virtually in every part of the country, covering 0.778 million hectares and yielding 19.3 million tonnes with a yield of around 24 tonnes per hectare (NHB, 2018-19) [16]. It is recognized as the "poor man's orange" in many countries owing to its excellent appearance and nutritious value. Tomatoes are indeed a major source of income for Indian farmers. 28.9 percent potato, 11.3 percent tomato, 10.3 percent onion, and 8.1 percent brinjal are the four primary vegetables that generate 58.6% of total vegetable output in our nation (Srivastava *et al.*, 2019) [24].

Total soluble solids and ascorbic acid of fruits are crucial for making processed products. Total soluble content in fruits increased by 1%, resulting in a 20% increase in processed product recovery. The presence of maximum ascorbic acid content in fruits improve nutritional value and also helps to retain tomato products in its original colour and flavour. Significant characteristics contributing to shelf life include fruit firmness, number of locules per fruit and pericarp thickness. Pericarp thickness of fruit is responsible for 60% of fruit firmness (Mishra *et al.*, 2020) [13]. Due to the nutritive benefits of tomatoes, it is important to identify the genotypes that are high in antioxidants, processing characteristics and fruit quality. The present study was carried out to characterize the quality of tomato genotypes.

Materials and Methods
The materials used for this study comprised of four crosses and seven genotypes *viz.*, PKM 1 × Acc. 90, Acc.14 × PKM 1, Acc.14 × Acc. 71, Acc. 65 × Acc. 71, PKM 1, Acc. 14, Acc. 65,

Acc. 71, Acc. 90, CO 3 and TNAU Tomato Hybrid CO 3 (COTH 3). The experiment was conducted with three replications in Randomized Block Design during kharif, 2021 at Western Block Farm, Horticultural College and Research Institute, Periyakulam of Theni District, Tamil Nadu. The seedlings were raised in protrays and transplanted to main field at an age of eighteen days with a spacing of 60×45 cm. The observations were recorded on fruit characteristics *viz.*, fruit shape, fruit colour, fruit length, fruit width, average fruit weight, pericarp thickness, number of locules per fruit, fruit firmness (kg/cm^2), total soluble solids (°Brix), ascorbic acid content (mg per 100 g) and titrable acidity (%).

Statistical analysis

This study was conducted in Randomized Block Design (RBD) with three replications. The observed data were analyzed by using AGRES and the obtained data was compared using analysis of variance with a significance level of $P \leq 0.05$ (Panse and Sukhatme, 1967) [17].

Results and Discussion

The analysis of variance for different quantitative fruit traits showed significant difference at $P \leq 0.05$ *viz.*, fruit length, fruit width, average fruit weight, pericarp thickness, number of locules per fruit, fruit firmness (kg/cm^2), total soluble solids (° Brix), ascorbic acid content (mg per 100 g) and titrable acidity (%). The mean sum of squares for all the traits are presented in Table 1.

***Per se* performance for morphological characters**

The tomato genotypes and crosses under study were morphologically characterized *viz.*, fruit shape, fruit colour, fruit length (cm), fruit width (cm), average fruit weight (g), pericarp thickness (mm), number of locules per fruit and its *per se* performance are presented in Table 2.

Fruit shape and colour

The traits *viz.*, shape and colour of the fruits were categorized by using plant descriptor (IPGRI). The different fruit shapes recorded by the genotypes *viz.*, slightly flattened (Acc. 14 × PKM 1), oblate (PKM 1, Acc. 14, Acc. 71, PKM 1 × Acc. 90), rounded (Acc. 14 × Acc. 71, Acc. 90) and high rounded (Acc.65 × Acc. 71, Acc. 65, CO 3, COTH 3). The different colour of the fruits recorded were red (Acc. 65 × Acc. 71, Acc. 65, CO 3, COTH 3), orange (Acc. 90, Acc.71, Acc. 14 × Acc. 71) and orange with green shoulder (PK M 1 × Acc. 90, Acc. 14 × PKM 1**,** Acc. 14, PKM 1). Similar results were reported by Adalid *et al.* (2010) and Khan *et al.* (2017) [1, 11].

Fruit length and width (cm)

Among the genotypes, the hybrid COTH 3 (4.29 cm) recorded significantly higher fruit length, followed by Acc. 14 × Acc.71 (4.14 cm) and the genotype Acc. 65 (2.92 cm) recorded the lowest fruit length compared to other genotypes. The highest fruit width of 5.13 cm, 5.11 cm and 5.06 cm was showed in PKM 1 × Acc.90, Acc. 71 and Acc. 14 × Acc.71 respectively. The genotype Acc. 65 recorded the lowest fruit width of 2.57 cm. Kumar *et al*. (2016) [12] reported that the fruit length ranged from 1.74 to 6.42 cm and fruit width from 0.74 to 6.50 cm. The fruit length and width ranged from 3.00 to 5.87 cm and 2.10 to 4.60 cm respectively as reported by Reddy *et al.* (2019) [21]. Narayan *et al.* (2020) [15] obtained fruit length from 3.92 to 5.43 cm and width from 4.10 to 5.27 cm, while Anuradha *et al.* (2021) [4] reported fruit length from 3.95 to 5.86 cm and fruit width from 4.34 to 6.00 cm.

Average fruit weight (g)

There was a significant difference among the genotypes and crosses studied for average fruit weight at $P \leq 0.05$. The highest fruit weight of 69.53 g was observed in Acc. 14 × Acc.71, followed by 66.08 g in Acc. 71, while the lowest fruit weight of 22.35 and 17.11 g was observed in Acc.65 × Acc.71 and Acc. 65 respectively. Similar findings were reported by Kumar *et al.* (2016) [12] from 1.43 to 111.53 g. Jatav *et al.* (2017) [10] obtained fruit weight which varied from 25.27 to 64.03 g. Similar results were also reported by Prakash *et al.* (2019) [18] and Anuradha *et al.* (2021) [4].

Pericarp thickness (mm)

Significant difference was observed for the trait pericarp thickness. The thickest pericarp was found in Acc. 14 × Acc.71 (5.44 mm)**,** followed by 5.04 mm in Acc. 71**,** whereas the lowest pericarp thickness was found in Acc. 65 with 3.06 mm. Similar findings were given by Kumar *et al*. (2019) wherein pericarp thickness ranged from 3.02 to 5.95 mm. Similar results were obtained by Reddy *et al.* (2019) [21] in which the pericarp thickness ranged from 2.50 to 8.10 mm. Verma *et al.* (2021) [26] reported that the pericarp thickness varied from 2.20 to 4.20 mm.

Number of locules per fruit

The number of locules per fruit among the genotypes and the crosses varied from 2.13 to 6.30 (Table 2). The hybrid Acc. 14 × PKM 1 recorded the highest number of locules per fruit (6.30)**,** followed by PKM 1 × Acc. 90 (6.03), PKM 1 (5.53), Acc. 90 (5.40). The genotypes Acc. 65, CO 3 and the hybrid Acc. 65 × Acc.71 recorded the lowest number of locules per fruit (2.13, 2.33 and 2.33) respectively. Similar result for this trait was reported by Jatav *et al*. (2017) [10] were the number of locules varied from 3.23 to 6.20. Rakha and Sabry (2019) [20] reported that the number of locules per fruit varied from 2.85 to 6.05. Reddy *et al.* (2019) [21] obtained locule numbers ranging from 2 to 5 and Ibaad *et al.* (2020) [8] reported 2 to 7 locules per fruit.

Physio-Chemical Characters

The observations are recorded on physio-chemical properties of different tomato genotypes and crosses includes fruit firmness (kg/cm^2), total soluble solids (°Brix), ascorbic acid content (mg per 100 g) and titrable acidity (%). The *per se* performance of the physio-chemical characters is given in Table 3.

Fruit firmness (kg/cm^2)

The observed data on mean value of fruit firmness varied from 1.15 kg/cm^2 to 2.27 kg/cm^2. The Acc. 14 × Acc. 71 expressed significant difference from other genotypes with the highest fruit firmness of 2.27 kg/cm^2, followed by Acc. 71 (2.09 kg/cm^2) and COTH 3 (2.06 kg/cm^2), while the lowest fruit firmness was observed in Acc. 65 (1.15 kg/cm^2). These results are in accordance with the findings of Sureshkumara *et al.* (2017) [25] and the fruit firmness ranged from 1.63 kg/cm^2 to 2.27 kg/cm^2. Ibaad *et al.* (2020) [8] obtained firmness which ranged from 0.58 to 1.07 kg/cm^2 and Narayan *et al.* (2020) [15] reported from 0.34 to 1.22 kg/cm^2.

Ascorbic acid (mg per 100 g)

The mean value of ascorbic acid content ranged from 15.43

mg per 100 g to 37.08 mg per 100 g. The genotype COTH 3 recorded the highest amount of ascorbic acid content (37.08 mg per 100 g)**,** followed by the genotype Acc. 71 and cross Acc. 14 × PKM 1 which recorded 35.50 mg ascorbic acid per 100 g. The lowest ascorbic acid content of 15.43 was found in Acc.90 and PKM 1. Similar variability in ascorbic acid content was reported by Cheema *et al.* (2013). Mitul *et al.* (2014) [6, 14] exhibited that the ascorbic acid content ranged from 15.52 mg per 100 g to 31.35 mg per 100 g. Reddy *et al.* (2019) [21] reported ascorbic acid content of 28.30 to 38.41 mg per 100 g. Ibaad *et al.* (2020) [8] reported ascorbic acid content that varied from 13.72 to 25.82 mg per 100 g.

Total Soluble Solids (°Brix)

The concentration of total soluble solids varied from 4.43°Brix to 5.40°Brix. Among the genotypes and crosses studied, the cross PKM 1 × Acc. 90 recorded the highest total soluble solids of 5.40°Brix, followed by Acc. 90 (5.07 °Brix), COTH 3 (5.00°Brix), whereas the lowest total soluble solid content was registered by the genotype Acc. 14 (3.97°Brix). Similar results were obtained by Alam *et al.* (2010), Sharma *et al*. (2013) [2, 22] who reported that the total soluble solids varied from 3.22 to 4.70°Brix. Prakash *et al.* (2019) [18] reported that the total soluble solids varied from 3.49 to 6.45°Brix, while Reddy *et al.* (2019) [21] reported TSS ranging from 3.12 to 4.73°Brix.

Titrable acidity (%)

The genotype PKM 1 (0.87%) registered the highest concentration of acid, followed by the cross Acc. 14 × Acc. 71 (0.80%), whereas the lowest concentration of acid was registered by the genotype Acc. 65 (0.41%). The results of this study were in agreement with the previous findings of Kumar *et al*. (2016) [12] where titrable acidity ranged from 0.28% to 0.60%. Kumar *et al.* (2019) reported that the titrable acidity ranged from 0.48% to 0.68%. Similar result was exhibited by Prakash *et al.* (2019) [18] where the titrable acidity ranged from 0.44 to 1.19%, while Ibaad *et al.* (2020) [8] recorded titrable acidity that varied from 0.17 to 0.37%.

Table 1: Analysis of variance (ANOVA) for fruit characteristics of different tomato genotypes

S. No	Characters	Mean Sum of Square		
		Replications df = 2	Genotypes df = 10	Error df = 20
1	Fruit length (cm)	0.012	0.587**	0.01
2	Fruit width (cm)	0.011148	2.0935**	0.01199
3	Average fruit weight (g)	5.88	748.74**	3.43
4	Number of locules per fruit	0.047	7.34**	0.042
5	Pericarp thickness (mm)	0.0138	1.4527**	0.0242
6	Fruit firmness (kg/cm^2)	0.0040	0.3951**	0.0101
7	Total soluble solids (°Brix)	0.0158	0.2729**	0.0154
8	Ascorbic acid content (mg per 100 g)	4.6446	182.353**	7.447
9	Titrable acidity (%)	0.00058	0.0720**	0.000605

****** Significant at 1% level of significance

Table 2: *Per se* performance of different tomato genotypes for morphological characteristics of fruits

S. No.	Crosses & Genotypes	Fruit shape	Fruit colour	Fruit length (cm)	Fruit width (cm)	Average fruit weight (g)	Pericarp thickness (mm)	No. of locules per fruit
1	Acc. 14 × PKM 1	Slightly flattened	Orange with green shoulder	3.52	4.08	44.13	3.89	6.30
2	PKM 1 × Acc. 90	Oblate	Orange with green shoulder	3.11	5.13	44.99	4.78	6.03
3	Acc.65 × Acc. 71	High rounded	Red	3.06	3.30	22.35	3.55	2.33
4	Acc. 14 × Acc. 71	Rounded	Orange	4.14	5.06	69.53	5.44	4.0
5	Acc. 65	High rounded	Red	2.92	2.57	17.11	3.06	2.13
6	Acc. 71	Oblate	Orange	3.65	5.11	66.08	5.04	5.07
7	Acc. 90	Rounded	Orange	3.36	3.47	45.36	4.71	5.40
8	Acc.14	Oblate	Orange with green shoulder	3.07	4.26	37.62	4.51	3.80
9	PKM 1	Oblate	Orange with green shoulder	3.31	4.38	43.44	4.72	5.53
10	COTH 3	High rounded	Red	4.29	4.39	42.00	4.85	3.07
11	CO 3	High rounded	Red	3.32	3.47	31.66	4.66	2.33
Grand mean		-	-	3.432	4.1112	42.206	4.4748	4.182
SEd ±		-	-	0.0819	0.0894	1.5132	0.1269	0.1685
CV (%)		-	-	2.92	2.66	4.39	3.47	4.94
CD (P = 0.05)		-	-	0.1708	0.1866	3.1564	0.2647	0.3516

Table 3: *Per se* performance of different tomato genotypes for Physio-biochemical characteristics of fruits

S. No.	Crosses & Genotypes	Fruit firmness (kg/cm^2)	Ascorbic acid (mg per 100g)	Total soluble solids (°Brix)	Titrable acidity (%)
1	Acc. 14 × PKM 1	1.50	35.50	4.67	0.67
2	PKM 1 × Acc. 90	1.96	21.60	5.40	0.54
3	Acc.65 × Acc. 71	1.81	32.41	4.50	0.47
4	Acc. 14 ×Acc. 71	2.27	30.87	4.57	0.80
5	Acc. 65	1.15	24.69	4.43	0.41
6	Acc. 71	2.09	35.50	4.57	0.50
7	Acc. 90	1.96	15.43	5.07	0.46
8	Acc.14	1.22	23.14	3.97	0.46
9	PKM 1	1.93	15.43	4.70	0.87

10	COTH 3	2.06	37.08	5.00	0.48
11	CO 3	1.64	26.23	4.53	0.51
Grand mean		1.78	27.078	4.77	0.55
SEd ±		0.0821	2.2282	0.1014	0.0201
CV (%)		5.65	10.08	2.60	4.45
CD (P = 0.05)		0.1713	4.6479	0.2115	0.0419

Conclusion

The quality of the fruits is important to maintain human diet. The ultimate objective of this study was to determine the tomato genotype with good morphological and physio-chemical characteristics. The genotypes and crosses observed with superior quality characteristics were PKM 1 × Acc. 90 for total soluble solids, COTH 3, Acc. 71 and Acc. 14 × PKM 1 for ascorbic acid content, Acc. 14 × Acc. 71 for fruit firmness, PKM 1 and Acc. 14 × Acc. 71 for acidity. The genotypes identified with superior morphological characteristics were Acc. 14 × PKM 1, PKM 1 × Acc. 90, Acc. 14, PKM 1 for fruits with green shoulder, Acc. 14 × Acc. 71 for fruit length and width, average fruit weight and pericarp thickness and Acc. 14 × PKM 1 for number of locules per fruit. Due to nutritional value of tomato, it is important to develop cultivars with good fruit quality and characteristics suitable for processing (Dar and Sharma, 2011) [7].

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