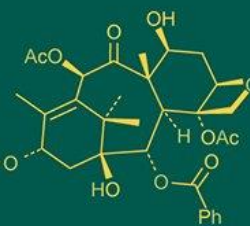
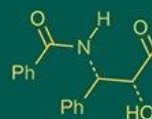


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(9): 450-455
www.biochemjournal.com
Received: 02-07-2026
Accepted: 05-08-2026

Shreya P Wasre
MSc. Scholar, Department of
Vegetable Science, Post
Graduate Institute, Dr.
PDKV, Akola, Maharashtra,
India

VS Kale
Professor (CAS), Department
of Vegetable Science, Dr.
PDKV, Akola, Maharashtra,
India

AM Sonkamble
Professor and Head,
Department of Vegetable
Science, Dr. PDKV, Akola,
Maharashtra, India

PV Jadhav
Professor, Biotechnology
Centre and Agricultural
Botany, Post Graduate
Institute, Dr. PDKV, Akola,
Maharashtra, India

ST Ingle
Professor (CAS), Department
of Plant Pathology, Post
Graduate Institute, Dr.
PDKV, Akola, Maharashtra,
India

Corresponding Author:
Shreya P Wasre
MSc. Scholar, Department of
Vegetable Science, Post
Graduate Institute, Dr.
PDKV, Akola, Maharashtra,
India

Per se performance of parents and F_1 hybrids for growth, yield and quality traits of tomato

Shreya P Wasre, VS Kale, AM Sonkamble, PV Jadhav and ST Ingle

DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i9Sf.9867>

Abstract

The present study was carried out to evaluate the performance of tomato parents and their F_1 hybrids for various growth, yield and quality traits. The mating design followed was line $\times$ tester to develop twenty-four F_1 hybrids by using eight lines, namely TBC-2-3, TBC-2-4, TBC-2-5, TBC-2-6, TBC-2-8, TBC-2-9, TD-13 and TD-16, which were crossed with three testers, namely Arka Vikas, Kashmir-1 and PKM-1. The parents and F_1 hybrids were evaluated using a Randomized Block Design with two replications during kharif 2025. The genotypes were evaluated for plant height at 30, 60 and 90 days after transplanting, number of primary branches per plant, leaf area, number of flowers per cluster, fruit set, fruit diameter, average fruit weight, number of fruits per cluster, number of fruits per plant, yield per plant, total soluble solids, titratable acidity, shelf life, number of locules, pericarp thickness and fruit firmness. Significant variation was observed among the genotypes for all the traits evaluated. Considerable variation in fruit shape and size was also observed among the parents and hybrids, with relatively larger differences evident among the hybrids, which may be attributed to the contrasting fruit size characteristics of their parental genotypes. Among the parental genotypes, Arka Vikas had the highest plant height at 30 and 60 days, whereas TBC-2-9 recorded the highest plant height at 90 days. Among the hybrids, TD-13 $\times$ Arka Vikas, TBC-2-6 $\times$ Arka Vikas and TBC-2-6 $\times$ Kashmir-1 showed the highest plant height at 30, 60 and 90 days, respectively. Line TD-16 had the highest average fruit weight among the parental genotypes, whereas TD-16 $\times$ PKM-1 recorded the highest average fruit weight and yield per plant among the evaluated hybrids. TBC-2-5 $\times$ Kashmir-1 recorded the highest number of primary branches per plant and the highest fruit firmness among the hybrids. The results revealed considerable diversity in per se performance and identified promising parents and F_1 hybrids for individual growth, yield and quality attributes, while the observed diversity in fruit shape and size further demonstrated the influence of contrasting parental characteristics on hybrid performance.

Keywords: Tomato, fruit diameter, fruit number, fruit weight, fruit yield, line $\times$ tester

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the important vegetable crops belonging to the family Solanaceae, commonly known as the nightshade family. The family comprises more than 3000 species. The *S. esculentum* complex comprises seven species that are readily crossable with cultivated tomato and have served as valuable sources of genetic variability for tomato improvement (Mueller *et al.*, 2005) [15]. Tomato possesses a distinctive nutritional and phytochemical composition, providing important nutrients and bioactive compounds such as vitamin C, vitamin A in the form of carotenoids, dietary fibre, potassium and the antioxidant lycopene. These compounds contribute to the nutritional and health-promoting value of tomato and have been associated with beneficial effects such as blood purification and protection against certain types of cancer (Burton-Freeman and Reimers, 2011) [6]. In addition, the presence of various phytochemicals in tomato fruits may influence post-harvest characteristics, including shelf life and uniformity of ripening, and can help reduce post-harvest losses (Arah *et al.*, 2015; Pavan *et al.*, 2022) [3, 17].

Tomato is an important vegetable crop grown widely across the world and is valued for its taste, nutritional content and diverse uses. It is cultivated on about 4.76 million hectares globally, with an annual production of nearly 182 million tonnes. (Esposito *et al.* 2020) [10]. The major tomato producing states in the country are Andhra Pradesh, Madhya Pradesh, Karnataka, Gujarat, Bihar, Odisha, West Bengal, Telangana, Chhattisgarh, Haryana, Tamil Nadu, Uttar Pradesh, and Maharashtra.

These states account for 91% of the total production of the country. Area under tomato cultivation in India is around 8.48 lakh Ha and production is estimated to be 203.97 lakh T (Anonymous 2024-25) ^[2].

Growth attributes such as plant height, number of primary branches and leaf area provide an indication of the vegetative development and overall plant architecture. Flower production and fruit set are important components of fruit-bearing ability, while fruit diameter, fruit weight, number of fruits and yield per plant are directly associated with the productive performance of a genotype. In addition to yield, fruit quality plays an important role in determining consumer acceptance and post-harvest performance. Traits such as total soluble solids, titratable acidity, shelf life, locule number, pericarp thickness and fruit firmness are therefore important considerations in tomato improvement programmes (Bertin and Génard, 2018; Bhat *et al.*, 2022) ^[4, 5].

Mean performance, or per se evaluation, is one of the basic yet important steps in the characterization of breeding material. It provides an initial understanding of the performance of different genotypes and helps in identifying those with desirable phenotypic characteristics before undertaking detailed genetic analyses. In the present study, the selected tomato parents and their F₁ hybrids were evaluated based on their mean performance for a range of growth, flowering, fruit, yield and quality traits. The

evaluation was aimed at understanding the extent of variation among the genotypes and identifying parents and hybrids that performed well for specific desirable traits.

Materials and Methods

Experimental material

The experimental material consisted of eight parental lines, namely TBC-2-3, TBC-2-4, TBC-2-5, TBC-2-6, TBC-2-8, TBC-2-9, TD-13 and TD-16, and three testers, namely Arka Vikas, Kashmir-1 and PKM-1 and the eight lines were crossed with three testers to produce twenty four F₁ hybrids.

Traits Observed

Observations were taken for growth and flowering parameters which are plant height, number of primary branches per plant, leaf area, number of flowers per cluster where plant height was measured at 30, 60 and 90 days after transplanting (DAT), number of primary branches was recorded per plant and leaf area was expressed in cm², flower number was recorded per cluster. Yield and yield contributing characters consisted of fruit set as percentage, fruit diameter in centi-meter, average fruit weight in grams, number of fruits per cluster and number of fruits per plant, yield was expressed as kilogram per plant. Quality parameters included were Total soluble solids (TSS), titratable acidity and shelf life, number of locules, pericarp thickness and fruit firmness were recorded and evaluated.

Table 1: Mean performance for growth and flowering parameters of parents

Genotype	Plant height at 30 DAT (cm)	Plant height at 60 DAT (cm)	Plant height at 90 DAT (cm)	Primary branches/plant	Leaf area (cm ²)	Flowers/cluster
Lines						
TBC-2-3	35.14	58.35	90.57	5.00	30.81	4.80
TBC-2-4	31.80	61.08	96.27	5.40	29.12	4.70
TBC-2-5	37.17	67.21	101.47	4.30	30.46	3.80
TBC-2-6	35.37	68.17	99.47	5.15	30.71	5.60
TBC-2-8	35.90	66.96	101.46	4.20	29.69	4.80
TBC-2-9	35.83	73.81	112.06	5.33	30.04	6.55
TD-13	31.16	67.35	102.11	4.40	28.90	6.60
TD-16	29.20	60.76	92.39	4.80	30.01	4.75
Tester						
Arka Vikas	41.95	81.88	99.68	5.10	30.68	5.85
Kashmir-1	37.52	74.04	104.27	3.70	30.47	6.75
PKM-1	33.21	73.10	110.49	5.10	30.77	2.80
SE (± Mean)	0.61	0.73	1.03	0.08	0.07	0.10
C.D 5%	1.77	2.11	2.96	0.24	0.21	0.30

Table 2: Mean performance for growth and flowering parameters of F₁ hybrids

Genotype	Plant height 30 DAT (cm)	Plant height 60 DAT (cm)	Plant height 90 DAT (cm)	Primary branches/plant	Leaf area (cm ²)	Flowers/cluster
TBC-2-3 × Arka Vikas	41.84	91.68	114.91	5.30	29.07	4.50
TBC-2-3 × Kashmir-1	45.64	94.97	123.99	5.40	29.23	4.55
TBC-2-3 × PKM-1	51.94	98.21	123.32	5.50	29.26	4.50
TBC-2-4 × Arka Vikas	40.74	84.64	114.03	5.30	30.92	4.55
TBC-2-4 × Kashmir-1	38.18	87.03	107.92	4.70	29.03	7.70
TBC-2-4 × PKM-1	42.38	89.60	100.82	6.00	29.42	6.70
TBC-2-5 × Arka Vikas	36.15	76.98	98.49	4.40	29.45	7.50
TBC-2-5 × Kashmir-1	47.34	86.48	109.49	6.90	29.23	6.60
TBC-2-5 × PKM-1	42.91	85.92	106.10	5.30	29.54	5.10
TBC-2-6 × Arka Vikas	52.64	104.40	117.23	4.30	28.79	5.90
TBC-2-6 × Kashmir-1	46.74	95.04	126.41	5.30	29.04	4.90
TBC-2-6 × PKM-1	39.43	77.76	97.55	4.90	29.91	4.95
TBC-2-8 × Arka Vikas	40.78	86.09	106.10	5.20	28.59	6.80
TBC-2-8 × Kashmir-1	41.09	86.71	109.09	5.30	29.55	6.45
TBC-2-8 × PKM-1	39.67	87.23	106.94	5.30	28.48	4.45
TBC-2-9 × Arka Vikas	43.88	82.77	102.16	5.40	28.28	4.75

TBC-2-9 × Kashmir-1	46.98	85.24	106.73	4.40	29.30	5.85
TBC-2-9 × PKM-1	45.52	87.88	108.51	5.90	29.61	7.80
TD-13 × Arka Vikas	54.49	99.00	124.94	5.70	29.48	6.05
TD-13 × Kashmir-1	37.92	84.78	103.40	5.10	28.46	7.80
TD-13 × PKM-1	44.75	76.82	103.77	4.90	29.77	3.70
TD-16 × Arka Vikas	53.57	99.20	123.54	4.40	30.88	5.60
TD-16 × Kashmir-1	39.27	82.81	118.14	4.10	28.58	6.50
TD-16 × PKM-1	43.19	97.48	106.57	4.40	30.81	4.65
SE (±Mean)	1.08	2.15	0.42	0.14	0.18	0.26
C.D 5%	3.12	6.18	1.89	0.42	0.51	0.76

Table 3: Mean performance for yield and yield contributing parameters of parents

Genotype	Fruit set (%)	Fruits/cluster	Fruit diameter (cm)	Average fruit weight (g)	Fruits/plant	Yield/plant (kg)
Lines						
TBC-2-3	72.80	4.40	3.39	25.40	83.07	2.11
TBC-2-4	62.00	4.30	3.30	22.02	87.65	1.93
TBC-2-5	71.00	3.40	2.98	17.46	79.61	1.38
TBC-2-6	66.50	5.35	2.32	16.34	123.01	1.72
TBC-2-8	64.66	4.45	3.50	21.65	64.67	1.72
TBC-2-9	67.53	6.30	3.56	38.05	49.41	1.48
TD-13	66.00	6.55	4.29	42.52	40.22	1.71
TD-16	54.00	4.40	5.65	65.51	36.03	2.36
Tester						
Arka Vikas	63.00	5.40	3.01	22.04	66.70	1.47
Kashmir-1	54.00	6.40	3.00	22.56	69.15	1.56
PKM-1	57.00	2.40	5.08	58.94	38.17	2.24
SE (±Mean)	1.75	0.44	0.82	0.11	0.45	0.02
C.D 5%	5.03	1.27	2.36	0.34	1.30	0.07

Table 4: Mean performance for yield and yield contributing parameters of F₁ hybrids

Genotype	Fruit set (%)	Fruits/cluster	Fruit diameter (cm)	Average fruit weight (g)	Fruits/plant	Yield/plant (kg)
TBC-2-3 × Arka Vikas	56.50	4.45	3.32	26.68	53.97	1.43
TBC-2-3 × Kashmir-1	59.00	4.45	3.25	33.47	44.82	1.51
TBC-2-3 × PKM-1	57.50	4.40	3.30	35.49	45.36	1.60
TBC-2-4 × Arka Vikas	69.00	4.55	3.46	25.95	59.73	1.54
TBC-2-4 × Kashmir-1	56.20	7.60	2.37	18.54	99.24	1.83
TBC-2-4 × PKM-1	59.50	5.50	3.30	28.49	52.30	1.49
TBC-2-5 × Arka Vikas	59.50	6.60	3.26	31.34	51.37	1.61
TBC-2-5 × Kashmir-1	54.00	6.60	3.29	35.92	40.09	1.44
TBC-2-5 × PKM-1	76.00	4.55	3.59	43.89	59.47	2.61
TBC-2-6 × Arka Vikas	61.80	5.55	2.57	17.71	118.01	2.08
TBC-2-6 × Kashmir-1	72.00	4.50	3.52	28.27	64.73	1.82
TBC-2-6 × PKM-1	55.80	4.80	4.60	43.15	39.86	1.71
TBC-2-8 × Arka Vikas	57.20	6.45	3.23	36.22	41.97	1.52
TBC-2-8 × Kashmir-1	54.80	6.40	3.50	35.18	42.64	1.50
TBC-2-8 × PKM-1	55.00	4.20	4.23	55.96	43.60	2.43
TBC-2-9 × Arka Vikas	81.00	4.40	3.65	46.67	48.85	2.27
TBC-2-9 × Kashmir-1	59.20	5.85	2.89	22.78	60.14	1.36
TBC-2-9 × PKM-1	62.20	7.40	3.06	27.99	60.74	1.71
TD-13 × Arka Vikas	55.00	6.00	3.69	39.16	48.77	1.91
TD-13 × Kashmir-1	54.20	5.35	4.72	49.49	41.02	2.03
TD-13 × PKM-1	78.00	3.55	4.92	56.78	42.44	2.41
TD-16 × Arka Vikas	60.20	5.50	3.70	46.25	52.54	2.42
TD-16 × Kashmir-1	75.00	6.45	4.76	55.19	38.41	2.11
TD-16 × PKM-1	70.20	4.55	7.45	81.15	38.08	3.09
SE (±Mean)	1.76	1.07	0.21	1.36	1.17	0.04
C.D 5%	5.06	3.08	0.61	3.91	3.36	0.12

Table 5: Mean performance for quality parameters of parents

Genotype	TSS (°Brix)	Titrateable acidity (%)	Shelf life	No. of locules in tomato	Pericarp thickness (mm)	Fruit firmness (N)
Lines						
TBC-2-3	7.22	0.42	11.12	2.00	2.60	0.63
TBC-2-4	5.64	0.38	10.00	2.50	2.91	0.69
TBC-2-5	5.85	0.39	10.53	3.10	2.46	0.66
TBC-2-6	6.47	0.41	12.75	2.00	1.76	0.51
TBC-2-8	6.39	0.39	11.46	3.10	2.88	0.70
TBC-2-9	5.33	0.33	10.50	2.00	2.79	0.54
TD-13	6.15	0.38	9.61	4.00	4.07	0.61
TD-16	5.80	0.41	10.36	4.50	4.17	0.70
Tester						
Arka Vikas	5.20	0.34	12.83	3.70	4.18	0.64
Kashmir-1	5.50	0.32	11.31	3.50	2.39	1.01
PKM-1	5.00	0.28	13.47	5.50	4.10	0.77
SE (±Mean)	0.06	0.01	0.19	0.17	0.07	0.01
C.D 5%	0.19	0.04	0.55	0.50	0.22	0.04

Table 6: Mean performance for quality parameters of F₁ hybrids

Genotype	TSS (°Brix)	Titrateable acidity (%)	Shelf life	No. of locules in tomato	Pericarp thickness (mm)	Fruit firmness (N)
TBC-2-3 × Arka Vikas	5.30	0.34	15.95	2.00	2.49	0.60
TBC-2-3 × Kashmir-1	6.55	0.31	12.97	2.10	2.07	0.72
TBC-2-3 × PKM-1	5.50	0.29	11.89	2.20	1.86	0.76
TBC-2-4 × Arka Vikas	6.55	0.34	13.72	3.10	2.54	0.65
TBC-2-4 × Kashmir-1	7.30	0.37	12.21	4.20	3.01	0.52
TBC-2-4 × PKM-1	7.10	0.26	12.82	2.00	3.40	1.04
TBC-2-5 × Arka Vikas	5.20	0.42	11.75	2.10	3.38	0.56
TBC-2-5 × Kashmir-1	6.90	0.38	13.05	3.10	3.19	1.11
TBC-2-5 × PKM-1	4.80	0.26	15.33	2.00	4.62	0.65
TBC-2-6 × Arka Vikas	4.30	0.31	12.92	2.00	3.09	0.59
TBC-2-6 × Kashmir-1	5.20	0.30	15.51	3.50	3.46	0.61
TBC-2-6 × PKM-1	5.45	0.32	11.72	4.10	2.54	0.85
TBC-2-8 × Arka Vikas	7.40	0.32	15.11	2.50	3.03	0.54
TBC-2-8 × Kashmir-1	5.89	0.36	11.82	2.10	4.02	0.62
TBC-2-8 × PKM-1	5.32	0.35	11.24	2.60	4.30	0.85
TBC-2-9 × Arka Vikas	5.40	0.26	14.09	2.00	3.62	0.60
TBC-2-9 × Kashmir-1	6.35	0.25	15.65	3.10	3.85	0.61
TBC-2-9 × PKM-1	5.90	0.34	12.03	2.00	3.83	0.66
TD-13 × Arka Vikas	5.76	0.37	14.22	2.00	4.10	0.55
TD-13 × Kashmir-1	6.25	0.29	13.20	4.50	3.27	0.64
TD-13 × PKM-1	5.85	0.28	13.28	2.00	3.30	0.60
TD-16 × Arka Vikas	7.85	0.36	13.35	4.50	3.28	0.67
TD-16 × Kashmir-1	5.21	0.34	13.20	4.50	2.89	0.86
TD-16 × PKM-1	4.65	0.34	16.11	5.50	5.55	0.80
SE (±Mean)	0.12	0.01	0.35	0.27	0.15	0.06
C.D 5%	0.56	0.04	1.03	0.80	0.47	0.19

Mean performance of parents and F₁ hybrids

Growth and flowering traits

Considerable variation was observed among the parental genotypes and their F₁ hybrids for growth and flowering characters, indicating the presence of useful variability for these traits. Plant height showed a progressive increase from 30 to 90 days after transplanting, although the magnitude of increase differed among genotypes. Among the Testers, Arka Vikas recorded the highest plant height at 30 DAT (41.95 cm) and 60 DAT (81.88 cm), while PKM-1 attained the highest plant height at 90 DAT (110.49 cm). Among the lines, TBC-2-9 showed comparatively greater plant height at 60 and 90 DAT (73.81 and 112.06 cm, respectively), suggesting better vegetative growth and sustained plant development. The hybrids generally showed greater plant height than their respective parents at different stages, although the magnitude varied with the cross combination. TD-13 × Arka Vikas recorded the highest plant height at 30 DAT (54.49 cm), whereas TBC-2-6 × Arka Vikas was the

tallest hybrid at 60 DAT (104.40 cm). At 90 DAT, TBC-2-6 × Kashmir-1 recorded the maximum plant height (126.41 cm), closely followed by TD-13 × Arka Vikas (124.94 cm) and TBC-2-3 × Kashmir-1 (123.99 cm). These differences indicate that the choice of parental combination had a noticeable influence on vegetative growth. The variation observed in plant height at different stages of crop growth in the present study was in agreement with the findings of Renuka *et al.* (2019) ^[18] and Pavan *et al.* (2022) ^[17] who reported significant differences in plant height among tomato genotypes and their F₁ hybrids.

Number of primary branches also differed among genotypes. Among the parents, TBC-2-4 had the highest number of primary branches (5.40), followed by TBC-2-9 (5.33), while among the hybrids, TBC-2-5 × Kashmir-1 recorded the maximum number of primary branches (6.90). A greater number of branches can provide more sites for flowering and fruit development and may therefore contribute indirectly to productivity. Leaf area varied within

a relatively narrow range among the genotypes. The highest leaf area among the parents was observed in TBC-2-3 (30.81 cm²), while TBC-2-4 × Arka Vikas recorded the highest leaf area among hybrids (30.92 cm²). The results obtained for the number of primary branches per plant were in accordance with the findings of Bhat *et al.* (2022)^[5] and Pavan *et al.* (2022)^[17], who also reported considerable variation among tomato genotypes for the traits.

Flower number per cluster also showed appreciable variation. Among the parents, Kashmir-1 recorded the highest number of flowers per cluster (6.75), closely followed by TD-13 (6.60) and TBC-2-9 (6.55). Among the hybrids, TBC-2-9 × PKM-1 recorded the highest value (7.80), along with TD-13 × Kashmir-1 (7.80). The relatively higher flower production in these combinations may be useful for increasing fruit-bearing potential, although actual yield would also depend on fruit set and subsequent fruit development. The results of flower per cluster was in accordance with findings of Renuka *et al.* (2019)^[18].

Yield and yield-contributing traits

Marked variation was observed among parents and F₁ hybrids for fruit set, fruits per cluster, fruit diameter, average fruit weight, number of fruits per plant and yield per plant. Among the parental genotypes, TBC-2-3 recorded the highest fruit set (72.80%), while TD-16 had the highest fruit diameter (5.65 cm), average fruit weight (65.51 g) and yield per plant (2.36 kg). TBC-2-6 produced the highest number of fruits per plant (123.01), indicating its potential for high fruit-bearing capacity despite having comparatively smaller fruits. TD-13 recorded the highest number of fruits per cluster (6.55) among the lines, while Kashmir-1 recorded 6.40 fruits per cluster among the testers.

The hybrids displayed substantial differences in yield components, demonstrating that parental combinations strongly influenced fruit production. The highest fruit set was recorded in TBC-2-9 × Arka Vikas (81.00%), followed by TD-13 × PKM-1 (78.00%) and TBC-2-5 × PKM-1 (76.00%). In terms of fruits per cluster, TBC-2-4 × Kashmir-1 recorded the highest value (7.60), followed by TBC-2-9 × PKM-1 (7.40), TBC-2-5 × Arka Vikas and TBC-2-5 × Kashmir-1 (6.60) findings showed similar results as Ghadge *et al.* (2019)^[11] and Khar and Arti (2019)^[14].

Fruit size and fruit weight varied considerably among the hybrids. TD-16 × PKM-1 recorded the highest fruit diameter (7.45 cm) and was also superior for yield per plant (3.09 kg). Other promising hybrids for yield included TBC-2-5 × PKM-1 (2.61 kg), TBC-2-8 × PKM-1 (2.43 kg), TD-16 × Arka Vikas (2.42 kg) and TD-13 × PKM-1 (2.41 kg) similar results were also observed by Chauhan *et al.* (2014)^[8], Ghadge *et al.* (2019)^[11], Bhat *et al.* (2022)^[5] and Renuka *et al.* (2019)^[18].

The number of fruits per plant also contributed to differences in yield. TBC-2-6 × Arka Vikas recorded the highest number of fruits per plant (118.01), followed by TBC-2-4 × Kashmir-1 (99.24). These crosses did not record the highest yield due to presence of variation in fruit sizes in parental as well as F₁ genotypes, indicating that fruit number alone was not sufficient to determine overall productivity. In contrast, crosses involving TD-16, particularly TD-16 × PKM-1, combined relatively high fruit size-related performance with greater yield per plant. The present findings are in agreement with the earlier reports of Naorem *et al.* (2012)^[16], Chauhan *et al.* (2014)^[8], Ghadge *et al.*

(2019)^[11], Renuka *et al.* (2019)^[18], Bhat *et al.* (2022)^[5] and Pavan *et al.* (2022)^[17] who observed considerable variation in the number of fruits per plant among tomato parents and F₁ hybrids and identified superior genotypes for this trait. However, Kanthaswamy *et al.* (1989)^[13] reported a reduction in the number of fruits per plant in certain tomato crosses. Such differences in fruit number among crosses may be attributed to the presence and interaction of favourable and unfavourable genes governing this trait in the parental genotypes involved.

Thus, the yield data clearly demonstrated differences among cross combinations. TD-16 × PKM-1 emerged as one of the most promising hybrids for overall yield performance of 3.09 kg, while other crosses showed specific superiority for fruit set, fruit number or individual fruit characteristics. Such crosses may be useful in further breeding programmes aimed at combining desirable yield components. The results of the present investigation are in accordance with the findings of Chauhan *et al.* (2014)^[8], Ghadge *et al.* (2019)^[11], Renuka *et al.* (2019)^[18], Bhat *et al.* (2022),^[5] Pavan *et al.* (2022)^[17] and Singh *et al.* (2022)^[19] who reported superior fruit yield in selected tomato F₁ hybrids compared with their respective parental genotypes and evaluated checks.

Quality traits

The parental and hybrid genotypes also showed considerable variation for quality attributes, including total soluble solids (TSS), titratable acidity, shelf life, number of locules, pericarp thickness and fruit firmness. Among the parents, the available data showed differences in TSS, acidity and post-harvest characteristics, indicating variation in fruit quality. TD-16 was particularly notable among the parental material for fruit firmness, while the testers also differed considerably for shelf life and other quality parameters. Among the F₁ hybrids, TD-16 × Arka Vikas recorded the highest TSS (7.85 °Brix), followed by TBC-2-8 × Arka Vikas (7.40 °Brix) and TBC-2-4 × Kashmir-1 (7.30 °Brix). Higher TSS is generally desirable because it contributes to better soluble-solids content and can improve the eating quality and processing value of tomato fruits. TD-16 × PKM-1 recorded the highest shelf life (16.11 days), suggesting better potential for maintaining fruit quality after harvest. Variation was seen in titratable acidity. The hybrids ranged from 0.25 to 0.42 percent, with TBC-2-5 × Arka Vikas showing the highest acidity (0.42%), while TBC-2-9 × Kashmir-1 recorded the lowest value (0.25%). Differences in acidity may influence the balance between sweetness and sourness and therefore contribute to consumer acceptance and processing quality. The number of locules and pericarp thickness also differed among the hybrids. TD-16 × PKM-1 recorded the highest number of locules (5.50) and the greatest pericarp thickness (5.55 mm). These characteristics may be useful where firm, fleshy fruits with better structural strength are desired. Fruit firmness was highest in TBC-2-5 × Kashmir-1 (1.11 N), followed by TBC-2-4 × PKM-1 (1.04 N), while TD-16 × Kashmir-1 also showed relatively high firmness (0.86 N). Taken as whole, the quality traits showed that different hybrids possessed different combinations of desirable characteristics. TD-16 × Arka Vikas was notable for TSS, whereas TD-16 × PKM-1 was particularly promising for shelf life, locule number and pericarp thickness. TBC-2-5 × Kashmir-1 showed comparatively high fruit firmness. These hybrids therefore provide useful

material for selecting combinations with improved fruit quality and post-harvest performance. The present investigation was in close agreement with the findings of Joshi *et al.* (2005) ^[12], Droka (2012) ^[9], Agarwal *et al.* (2014) ^[1], Chandanshive and Rana (2015) ^[7], Renuka *et al.* (2019) ^[18], Bhat *et al.* (2022), ^[5] Pavan *et al.* (2022) ^[17] and Singh *et al.* (2022) ^[19].

Conclusion

The present investigation revealed considerable variation among the evaluated tomato genotype consisting eight tomato lines, three testers and twenty-four F₁ hybrids for growth, yield and quality traits, indicating good potential for further improvement through breeding. Among the growth traits, Arka Vikas and PKM-1 performed better for plant height, while the hybrids TBC-2-6 × Kashmir-1 and TD-13 × Arka Vikas recorded the greatest plant height, suggesting better vegetative vigour in these combinations.

For yield and its contributing traits, TD-16 was identified as the most promising parent, showing the highest fruit diameter, average fruit weight and yield per plant. TBC-2-6 also performed well, particularly for number of fruits per plant, although its overall yield was moderate. Among the hybrids, TD-16 × PKM-1 was the most outstanding combination. It recorded the highest average fruit weight (81.15 g), fruit diameter (7.45 cm) and yield per plant (3.09 kg) and also showed desirable values for shelf life, locule number and pericarp thickness. These attributes make this hybrid particularly promising for further evaluation and potential commercial use. Other combinations, including TBC-2-5 × PKM-1, TBC-2-8 × PKM-1, TD-13 × PKM-1 and TD-16 × Arka Vikas, also showed good yield performance and could be considered as promising alternatives.

The hybrids also differed considerably for fruit quality traits. TD-16 × Arka Vikas recorded the highest total soluble solids, whereas TBC-2-5 × Kashmir-1 showed the greatest fruit firmness. This indicates that desirable quality attributes were distributed among different hybrid combinations rather than being concentrated in a single genotype.

Overall, the study identified TD-16 and PKM-1 as valuable parents for tomato improvement, while TD-16 × PKM-1 emerged as the most promising hybrid for combining high yield with desirable fruit quality. These genotypes may therefore be effectively utilised in future breeding programmes aimed at developing high-yielding tomato hybrids with improved fruit quality and post-harvest keeping ability.

Acknowledgement

I would like to thank Dr. V. S. Kale, Professor, and Dr. A. M. Sonkamble, Professor and Head, Department of Vegetable Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, for their guidance and support throughout this work, and the Department of Vegetable Science, Dr. PDKV, Akola, for the facilities that made this investigation possible.

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