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Heterosis Studies for Yield and Quality traits in Tomato (*Solanum Lycopersicum*. L)

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Abstract
The present investigation on *Solanum Lycopersicum* L. was conducted using eight parental lines and twenty-eight F_1 hybrids developed through a half-diallel mating design to assess heterosis and genetic variability for growth, yield and quality traits. The analysis of variance (ANOVA) revealed highly significant differences among genotypes for all twelve traits studied, indicating the presence of wide genetic variability and the scope for effective selection and hybrid development. Both additive and non-additive gene actions were found to be important; however, the predominance of non-additive effects suggested that hybrid breeding would be the most effective approach for improvement. Marked heterosis was observed for fruit yield and its component traits. The hybrid Kashi Vishesh × Kashi Adarsh recorded the highest fruit yield (85.71 t ha^{-1}), showing 21.92% heterosis over mid-parent, 20.03% over better-parent, and 5.81% over the standard check. Significant positive heterosis was also observed for fruit length, diameter, and average fruit weight, while negative heterosis for days to 50 % flowering indicated earliness in several crosses. Quality parameters such as lycopene, ascorbic acid and The present investigation on *Solanum Lycopersicum* L. was conducted using eight parental lines and twenty-eight F_1 hybrids developed through a half-diallel mating design to assess heterosis and genetic variability for growth, yield, and quality traits. The analysis of variance (ANOVA) revealed highly significant differences among genotypes for all fifteen traits studied, indicating the presence of wide genetic variability and the scope for effective selection and hybrid development. Both additive and non-additive gene actions were found to be important; however, the predominance of non-additive effects suggested that hybrid breeding would be the most effective approach for improvement.
Marked heterosis was observed for fruit yield and its component traits. The hybrid Kashi Vishesh × Kashi Adarsh recorded the highest fruit yield (85.71 t ha^{-1}), showing 21.92% heterosis over mid-parent, 20.03% over better-parent, and 5.81% over the standard check. Significant positive heterosis was also observed for fruit length, diameter, and average fruit weight, while negative heterosis for days to 50 % flowering indicated earliness in several crosses. Quality parameters such as lycopene, ascorbic acid, total soluble solids, and firmness also exhibited positive heterosis, reflecting improved nutritional and post-harvest qualities in selected hybrids.
Overall, the ANOVA and heterosis results confirmed that genetic variability and dominance effects substantially influence yield and quality traits in tomato. Hybrids such as Kashi Vishesh × Kashi Adarsh, Kashi Adarsh × Krishnaprabha Shalmala, and Kashi Vishesh × Krishnaprabha Bhari emerged as promising combinations for commercial exploitation and future hybrid development programs.total soluble solids also exhibited positive heterosis, reflecting improved nutritional and post-harvest qualities in selected hybrids. Overall, the ANOVA and heterosis results confirmed that genetic variability and dominance effects substantially influence yield and quality traits in tomato. Hybrids such as Kashi Vishesh × Kashi Adarsh, Kashi Adarsh × Krishnaprabha Shalmala, and Kashi Vishesh × Krishnaprabha Bhari emerged as promising combinations for commercial exploitation and future hybrid development programs.

Keywords: Parents, Hybrids, Heterosis, yield, quality

Introduction
Tomato (*Solanum Lycopersicum* L.) is one of the most widely grown vegetable crops in the Solanaceous family, having an chromosomal number of 2n = 24. It is tropical day-neutral plant primarily self-pollinated take place. It grows in a variety of soils and climates. It is the most processed vegetable, It occupies second place in the world only after potatoes (Chaudhary, 1996) [8].

In India, the major tomato producing states are Madhya pradesh, Andhra Pradesh, Karnataka, Gujarat, Orissa, West Bengal, Maharashtra and Tamil Nadu with an annual production 21,320 metric tonnes with the productivity of roughly 24.400 metric tonnes per/ha from an area of 871 thousand hectares (Anon., 2023-24) [2]. Tomatoes are grown on 79,000 ha of land in Karnataka, yielding 2,007.33 metric tonnes of produce (Anon., 2023-24) [2]. Over the past 25 years, India's tomato production situation has undergone significant change due to the growing acceptance of hybrids for commercial cultivation.

Tomatoes are consumed fresh or processed into value-added products such as soup, ketchup, pickles, puree, and paste (Chadha *et al.*, 2002) [7]. They are nutritionally rich, containing vitamin C, lycopene, β-carotene, dietary fiber, and essential minerals (Kaur & Kapoor, 2008) [13]. Lycopene and antioxidants in tomato are associated with reduced risks of cancers, cardiovascular disorders, and other chronic diseases. Its role as a staple for both domestic use and the food industry makes it an economically vital crop, providing income to small farmers.

With India’s rising population and limited resources, increasing vegetable productivity is critical to meeting food demand (Anon., 2022) [3]. Hybrid seed technology has been central to yield improvement, offering uniformity, quality, pest resistance, and consumer appeal. However, existing cultivars often succumb to biotic and abiotic stresses, necessitating development of improved hybrids with attributes like earliness, high yield, and stress resistance. Genetic diversity is a valuable tool in tomato breeding, as hybrids from diverse parents often show higher heterosis (Lahbib *et al.*, 2012) [15].

Hybrid seeds are the key input in vegetable cultivation to achieve higher yields with higher quality. The primary cause of the sharp increase in vegetable production output in the latter part of the 20th century was hybrid crop seeds. Along with improved pest and disease resistance, the hybrids will give higher yields, more uniformity, acceptable colour, and increased consumer appeal.

Several new cultivars or hybrids of tomato have been developed from the public sector in the past 50 years to meet the diverse needs, varied situations and climates under which, tomato is grown. But with the passage of time, either these varieties become susceptible to many biotic and abiotic stresses the market demand changes, so it is imperative to develop such hybrids having a complex of valuable attributes, *viz.*, earliness, uniformity, good quality, high yield, resistance to diseases and adaptability to wider environmental conditions in the public sector too.

Genetic diversity plays an important role in breeding because hybrids derived from the lines of diverse origin exhibit more heterosis than those between closely related strains (Lahbib *et al.*, 2012; Srivastava *et al.*, 2014) [15, 22]. Although, tomato is a self-pollinated crop, there is genetic diversity not only in the morphological features, but also in the quality attributes (Amanullah *et al.*, 2011) [1].

The diversity could be utilized efficiently to increase productivity as well as quality of tomato is through application of different plant breeding methods. The improvement of its characters with high economic values often faces challenge when selecting parents. Therefore, the effective study for parent selection is highly needed. The observation on the performance of hybrid offspring’s can be conducted using diallel crossing method and its progeny test can be related to the combining ability which is very useful in determining the parent combination for the best progeny with potentially high productivity and other selected novel characters (Baihaki, 2000) [5].

Materials and Methods

The investigation “Heterosis Studies for Yield and Quality Traits in Tomato (*Solanum Lycopersicum* L.)” was conducted during 2024-25 at the College of Agriculture, Navile, Shivamogga, Karnataka (650 m MSL; 13°58′-14°01′ N, 75°34′-75°42′ E), falling under the Southern Transition Zone. The climate during experimentation (Jan-Apr 2025) was mild with mean temperatures of 18.7-33.8°C, 69.5 mm rainfall, and 77-79% relative humidity.

Experimental Material and Design

Eight diverse tomato genotypes were crossed in a half-diallel fashion to generate 28 F_1 hybrids. Two commercial checks (Arka Ananya, LHT-DON) were included. Hybrids were produced by hand emasculation and pollination, and F_1 seeds were raised during Dec 2024-Jan 2025.

Table 1: Salient features of parental materials and commercial checks used in the study

Sl. No	Parents	Source	Special features
1.	Manulaksmi	KAU	Resistant to bacterial wilt, semi determinate growth habit, high fruit size (50-55g), and fruit shape round.
2.	PKM-1	TNAU	Bacterial wilt, TLCV resistance, fruit weight of around 60-70g and green shoulder fruit.
3.	Kashi Vishesh	IIVR-Varanasi	TLCV resistance, tangy flavor, suitable for long distance transport.
4.	Kashi Adarsh	IIVR-Varanasi	TLCV resistance and high yielding variety (32-35t/ha)
5.	RFTS-1 (SHANT)	UHS-Bagalkot	Fusarium wilt, bacterial wilt, and TLCV resistant and good flavor.
6.	Krishnaprabha Bhari	UHS-Bagalkot	Fruit weight of 65-70g, fusarium wilt, bacterial wilt resistance and long shelf life.
7.	Krishnaprabha Tunga	UHS-Bagalkot	Wilt, bacterial spot, and tomato mosaic virus resistance. Sweet and tangy flavor, suitable for long distance transport
8.	Krishnaprabha Shalmala	UHS-Bagalkot	Long shelf life, both sweet and tart flavor and suitable for long distance transport
Commercial Checks			
1.	Arka Ananya	IIHR-Bangalore	High- yielding, determinate, developed from induced mutant of Co 1, Suitable for processing
2.	LHT-DON	Laxmi Inputs India Pvt. Ltd Bangalore	Long shelf life, High yielding, both sweet and tart flavor, bacterial wilt resistance.

The experiment was laid out in a Randomized Complete Block Design (RCBD) with 2 replications during summer 2025. Spacing of 0.60 × 0.45 m was followed, and recommended package of practices was adopted (FYM 20 t/ha, 250:250:250 NPK kg/ha, drip irrigation, weeding, and harvesting at maturity).

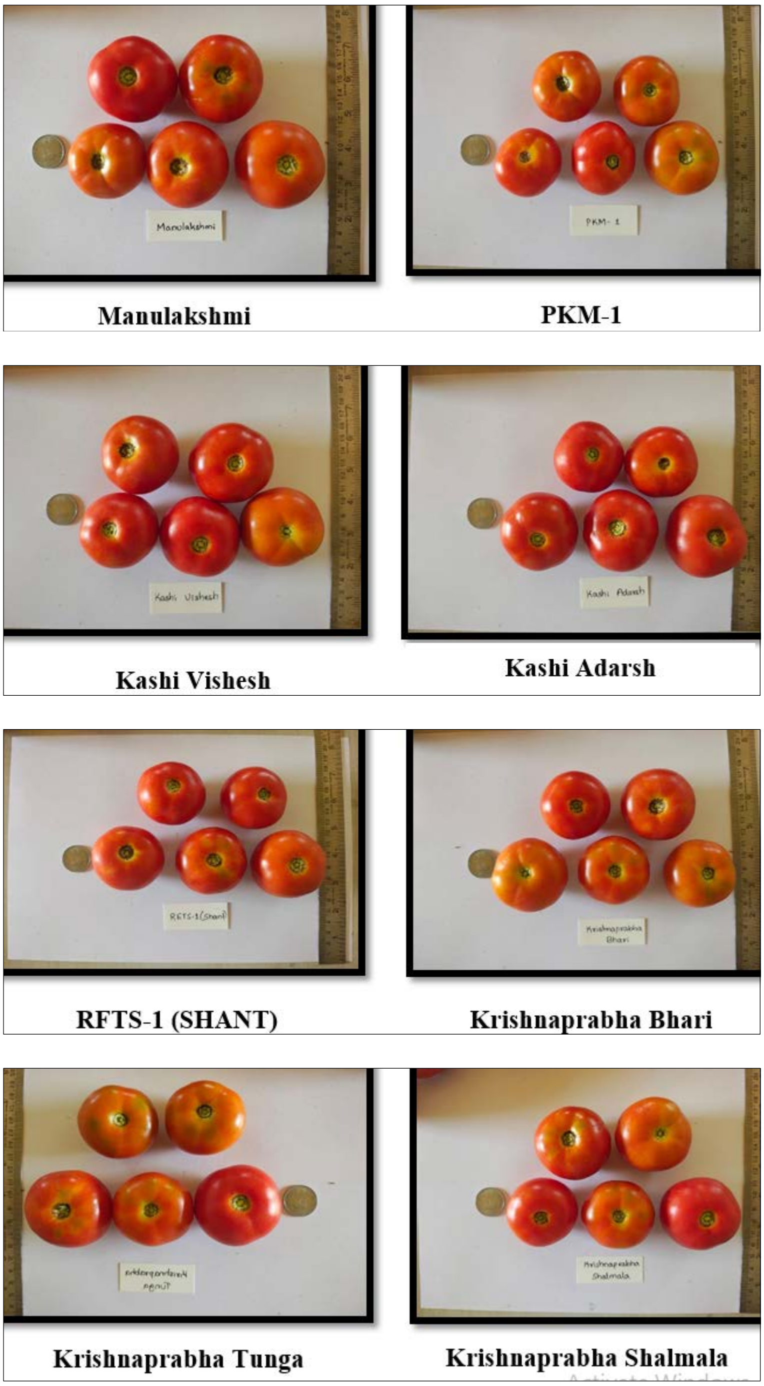
Observations Recorded

Data were collected from five randomly selected plants per replication for growth, yield, and quality traits:

- **Growth:** plant height, Number of branches, days to 50% flowering.
- **Fruit traits:** Fruit length, Fruit diameter, Number of locules, average weight.
- **Quality:** lycopene (Scott, 2001) [20], ascorbic acid (AOAC, 1999) [4], TSS (°Brix), shelf life.
- **Yield:** fruit yield per hectare.

Statistical Analysis

Data were subjected to ANOVA (Panse & Sukhatme, 1985; Gomez & Gomez, 1984) [25] under RBD. Heterosis was estimated over mid-parent, better parent, and standard checks (Turner, 1953; Hayes *et al*., 1955) [23, 12]. Significance of estimates was tested using t and f tests at 1% and 5% levels.



Result and Discussion

The analysis of variance (ANOVA) for 15 quantitative and quality traits in tomato (*Solanum Lycopersicum* L.) involving eight parental lines and their twenty-eight F_1 hybrids revealed highly significant differences among genotypes for all characters studied. This clearly indicated the existence of substantial genetic variability among the parental lines and their hybrids, providing ample scope for selection and heterosis breeding.

Highly significant mean squares were recorded for traits related to growth, yield and quality parameters such as plant height, number of branches, fruit length, fruit diameter, average fruit weight, total soluble solids (TSS), lycopene content, ascorbic acid and yield per hectare. The significant differences among treatments were further partitioned into parents, hybrids and parents versus hybrids, all of which exhibited distinct variability, signifying the presence of both additive and non-additive gene actions influencing these traits.

For growth traits, the treatment mean squares for plant height (60.94) were highly significant, demonstrating wide genetic diversity among the genotypes. Both parents and hybrids contributed significantly, while the contrast of parents versus hybrids also showed noticeable variation, suggesting that hybridization effectively combined diverse genetic backgrounds. Significant variation for these traits has been reported by Dharva *et al.* (2018) [10] and Barragan *et al.* (2019) [6], supporting the findings of this study.

Fruit-related traits such as fruit length (0.535) and fruit diameter (0.333) showed significant variation among both parents and hybrids, reflecting the presence of substantial diversity in fruit morphology and size. Similar variability has been observed in diallel analyses of tomato by Kumar *et al*. (2018) [14], indicating the complex inheritance of these traits involving both additive and dominance effects.

The average fruit weight (322.67) and fruit yield per hectare (38.38) exhibited significant mean squares, suggesting that yield and its components are under strong genetic control. The significant differences among hybrids for yield confirmed the potential for heterosis exploitation in tomato. These results are consistent with the findings of Hannan *et al*. (2007) [11] and Singh *et al.* (2019) [21], who reported considerable genetic variation for yield components in diallel populations of tomato.

Among quality traits, TSS (0.5867), ascorbic acid (13.89), and lycopene content (0.0087) also displayed significant differences, suggesting that nutritional quality in tomato can be enhanced through hybridization. The significance of parents *vs* hybrids for these biochemical traits further supports the existence of dominance and epistatic gene interactions, as also observed by Reddy *et al*. (2020) [18].

Overall, the ANOVA results established that both additive and non-additive genetic variances are important in controlling most of the studied traits. The predominance of significant hybrid variance indicates that non-additive effects, particularly dominance and epistasis, play a major role in determining yield and fruit quality. This provides a strong justification for heterosis breeding and hybridd development in tomato improvement programs.

Table 2: Analysis of variance for different characters in 8 × 8 half diallel crosses of tomato (Mean squares)

Source of variance	D.F	Plant height (cm)	Number of Branches	Days to 50 % flowering	Fruit length (cm)	Fruit Diameter (cm)	No. of locules	Average Fruit weight (g)
Replication	1	34.3896	0.0128	0.0098	0.0042	0.0183	0.0088	109.4706
Treatments	35	60.9433**	0.1057**	4.4142**	0.5350**	0.3325**	3.0943**	322.67431**
Parents	7	54.9039**	0.0939*	8.1428**	0.7526**	0.3136**	0.7657**	526.10082**
Hybrids	27	60.4731**	0.1126**	3.4788*	0.4980**	0.3398**	3.7393**	277.17692**
Parents vs Hybrids	1	115.9136	0.0003	3.5714	0.0125	0.2674**	1.9804**	127.1183
Error	35	29.4023	0.0266	1.4041	0.0128	0.0172	0.0968	40.9867

Source of variation	D. F	Lycopene content (mg/100g)	Ascorbic acid (mg/100g)	TSS (°Brix)	Fruit firmness (kg/cm²)	Shelf life (days)	Fruit yield t/ha
Replication	1	0.0024	8.5698	0.3334	0.1800	0.2005	84.2401
Treatments	35	0.0087*	13.8969*	0.5867**	1.2231**	1.0094*	38.3786**
Parents	7	0.0098*	9.6478	0.6455*	1.1469**	1.5714*	63.3918**
Hybrids	27	0.0085*	13.6309*	0.5673**	1.2042**	0.8986*	32.6399
Parents vs Hybrids	1	0.0067	50.8232*	0.6966*	2.2667**	0.0673	18.2306
Error	35	0.0043	5.3630	0.1648	0.1056	0.3536	22.0054

* and ** indicates significance at 5% and 1% respectively.

Per se Performance and Magnitude of Heterosis

The phenomenon of heterosis, or hybrid vigor, refers to the superior performance of F_1 hybrids over their parents for one or more traits of economic importance. In the present investigation on *Solanum Lycopersicum* L., eight parental lines and twenty-eight F_1 hybrids developed through a half-diallel mating design were evaluated to estimate the extent of heterosis for yield and its contributing traits. The analysis of variance revealed highly significant differences among genotypes for all traits, confirming the presence of ample genetic variability and the potential for heterosis exploitation. The overall findings indicated that heterosis played a key role in enhancing yield, earliness and fruit quality in tomato hybrids under study.

Heterosis for Growth and Earliness Traits

Growth attributes such as plant height, plant girth, and number of branches exhibited considerable heterosis. The hybrid Kashi Vishesh × Kashi Adarsh recorded high positive heterosis for plant height (17.36% over mid-parent and 14.88% over better-parent), suggesting that vigorous growth was influenced by dominance and epistatic gene actions. The cross Kashi Adarsh × Krishnaprabha Bhari also exhibited positive heterosis for plant girth (12.46% over mid-parent), indicating a more robust stem structure that supports higher fruit load. These results align with those of Dharva *et al.* (2018) [10] and Barragan *et al.* (2019) [6], who reported significant heterotic effects for vegetative traits in tomato due to non-additive gene action.

Earliness is one of the most desirable traits in tomato, allowing multiple cropping and early market entry. Significant negative heterosis for days to 50% flowering was observed in the hybrids PKM-1 × RFTS-1 (-17.91%), Kashi Vishesh × Kashi Adarsh (-15.63%), and RFTS-1 × Krishnaprabha Tunga (-13.48%), indicating earlier flowering compared to parents. Negative heterosis for earliness is highly beneficial for breeding short-duration hybrids. Similar results were reported by Dhaliwal and Cheema (2013) [9], who emphasized that hybrids showing negative heterosis for flowering and fruit set are desirable for early production systems.

Heterosis for Fruit and Yield-Contributing Traits

Significant and positive heterosis was observed for yield and its major component traits, including fruit length, fruit diameter, average fruit weight, number of locules, and fruit yield per plant. The hybrid Kashi Vishesh × Kashi Adarsh exhibited the highest fruit yield (85.71 t ha^{-1}), with heterosis of 21.92% over mid-parent, 20.03% over better-parent, and 5.81% over the standard check (LHT-DON). This hybrid also displayed superior performance for fruit diameter and average fruit weight, contributing directly to its high productivity. Kashi Adarsh × Krishnaprabha Shalmala (84.12 t ha^{-1}) and Kashi Adarsh × Krishnaprabha Tunga (82.51 t ha^{-1}) followed closely with substantial heterosis for yield and yield components. These results suggest that these parental combinations possess favorable dominant gene interactions. Similar observations have been made by Hannan *et al.* (2007) [11] and Singh *et al.* (2019) [21], who found that hybrids with high yield heterosis are typically associated with strong specific combining ability effects for yield components.

For fruit length and diameter, crosses such as RFTS-1 × Krishnaprabha Bhari and Kashi Adarsh × Krishnaprabha Bhari exhibited high positive heterosis, showing that these traits are primarily governed by non-additive gene action. Positive heterosis for fruit length and diameter enhances overall fruit size and market appeal. Kumar *et al*. (2018) [14] reported similar trends, where dominance and overdominance contributed significantly to the expression of fruit morphological traits.

Average fruit weight exhibited wide heterotic variation among hybrids. Kashi Vishesh × Kashi Adarsh recorded the highest positive heterosis for average fruit weight (26.31% over mid-parent and 16.67% over better-parent), indicating that favorable dominant alleles are concentrated in this cross. Positive heterosis for number of locules per fruit in Kashi Adarsh × Krishnaprabha Bhari further contributed to higher fruit size and weight, supporting the findings of Ray *et al.* (2015), who observed that fruit size and internal structure are influenced by dominance effects.

The significant heterosis observed for yield and related attributes suggests the predominance of non-additive gene action, corroborated by the low GCA:SCA ratio (<1) for most of these traits. This implies that hybrid breeding, rather than pure-line selection, would be the most effective approach for improving these characters. The results are consistent with the conclusions drawn by Kumar *et al.* (2018) [14] and Sharma *et al.* (2019) [21], who emphasized that non-additive effects govern the expression of yield and morphological traits in tomato.

Heterosis for Quality Traits

Quality traits such as total soluble solids (TSS), ascorbic acid, lycopene content and shelf life exhibited significant heterosis across the studied hybrids. The hybrid Kashi Vishesh × Krishnaprabha Bhari was particularly superior, recording the highest lycopene content (0.99 mg 100 g^{-1}) with 32.47% heterosis over mid-parent and 27.50% over better-parent. The same hybrid also expressed the highest ascorbic acid content (30.33 mg 100 g^{-1}) with 17.83% heterosis over mid-parent and 11.26% over better-parent, suggesting that nutritional enhancement can be effectively achieved through hybridization.

Positive heterosis for TSS was recorded in PKM-1 × RFTS-1 and RFTS-1 × Krishnaprabha Tunga, indicating improved sweetness and taste. Kashi Vishesh × Kashi Adarsh showed significant heterosis for firmness and shelf life, indicating its potential for better post-harvest handling and transportability. Such improvements in post-harvest traits are crucial for long-distance market supply and value chain efficiency. These observations agree with those of Reddy *et al.* (2020) [18], who reported that heterotic hybrids in tomato often combine high yield potential with superior quality parameters.

The variation in heterosis magnitude across different quality traits reflects the differential influence of dominance and epistasis. The observed positive heterosis for nutritional traits also aligns with Rai *et al.* (2008) [16], who emphasized that hybridization between diverse parents often enhances carotenoid and vitamin C content due to complementary gene action. Similarly, Sharma *et al.* (2019) [21] noted that firmness and shelf life improvements in heterotic hybrids are often linked to thicker rind and higher dry matter content.

Overall Heterotic Response and Genetic Implications

Across all the characters studied, heterosis was found to be more pronounced for yield and its components compared to morphological traits. The magnitude and direction of heterosis varied depending on the specific parental combination, confirming that cross-specific interactions contribute significantly to hybrid performance. The predominance of non-additive gene action, as revealed by lower GCA:SCA ratios, underscores the importance of hybrid breeding for tomato improvement. These findings are consistent with earlier reports by Singh *et al.* (2016) [24] and Kumar *et al.* (2018) [14], who highlighted the value of specific combining ability effects in the manifestation of heterosis.

Among the studied hybrids, Kashi Vishesh × Kashi Adarsh consistently performed best across yield, fruit quality, and shelf life traits, indicating broad-spectrum heterosis. Kashi Adarsh × Krishnaprabha Shalmala and Kashi Vishesh × Krishnaprabha Bhari also showed superior performance for specific traits such as yield and nutritional quality. The consistent superiority of these hybrids suggests favorable dominance interactions between alleles from genetically diverse parents.

From a breeding perspective, Kashi Vishesh, Kashi Adarsh, and Krishnaprabha Bhari emerged as promising general combiners and should be utilized in future hybridization programs. The presence of significant heterosis for both quantitative and qualitative traits indicates that hybrid breeding can simultaneously improve yield, earliness, and nutritional attributes in tomato. Similar conclusions were drawn by Dharva *et al.* (2018) [10] and Reddy *et al.* (2020) [18], who found that heterotic hybrids exhibit both agronomic and biochemical superiority.

Table 3: *Per se* performance and magnitude of heterosis for plant height (cm) in tomato.

Crosses	*Per se* value for plant height (cm)			Heterosis (%) over			
	Female	Male	F_1	MP	BP	SC (1)	SC (2)
Manulaksmi × PKM-1	62.94	62.08	64.91	3.84**	3.13**	-12.57**	-17.38**
Manulaksmi × Kashi Vishesh		55.09	66.91	13.38**	6.31**	-9.88**	-14.83**
Manulaksmi × Kashi Adarsh		78.36	67.18	-4.91**	-14.27**	-9.52**	-14.49**
Manulaksmi × RFTS-1 (SHANT)		62.44	66.12	5.47**	5.05**	-10.94**	-15.84**
Manulaksmi × Krishnaprabha Bhari		63.44	66.83	5.76**	5.34**	-9.99**	-14.93**
Manulaksmi × Krishnaprabha Tunga		67.84	68.20	4.30**	0.53	-8.14**	-13.19**
Manulaksmi × Krishnaprabha Shalmala		64.10	65.61	3.29**	2.36**	-11.63**	-16.48**
PKM-1 × Kashi Vishesh	62.08	55.09	76.17	30.02**	22.70**	2.58**	-3.04**
PKM-1 × Kashi Adarsh		78.36	63.50	-9.57**	-18.96**	-14.47**	-19.17**
PKM-1 × RFTS-1 (SHANT)		62.44	62.62	0.58	0.29	-15.66**	-20.29**
PKM-1 × Krishnaprabha Bhari		63.44	62.30	-0.73	-1.80**	-16.09**	-20.70**
PKM-1 × Krishnaprabha Tunga		67.84	64.32	-0.99	-5.19**	-13.37**	-18.13**
PKM-1 × Krishnaprabha Shalmala		64.10	62.82	-0.43	-2.00**	-15.39**	-20.04**
Kashi Vishesh × Kashi Adarsh	55.09	78.36	73.02	9.43**	-6.81	-1.65**	-7.05**
Kashi Vishesh × RFTS-1 (SHANT)		62.44	63.69	8.38**	2.00**	-14.22**	-18.93**
Kashi Vishesh × Krishnaprabha Bhari		63.44	76.23	28.63**	20.16**	2.66**	-2.97**
Kashi Vishesh × Krishnaprabha Tunga		67.84	59.46	-3.26**	-12.35**	-19.91**	-24.31**
Kashi Vishesh × Krishnaprabha Shalmala		64.10	67.79	13.75**	5.76**	-8.70**	-13.71**
Kashi Adarsh × RFTS-1 (SHANT)	78.36	62.44	67.78	-3.72**	-13.50**	-8.71**	-13.72**
Kashi Adarsh × Krishnaprabha Bhari		63.44	65.19	-8.05**	-16.81**	-12.20**	-17.02**
Kashi Adarsh × Krishnaprabha Tunga		67.84	64.42	-11.87**	-17.79**	-13.23**	-18.00**
Kashi Adarsh × Krishnaprabha Shalmala		64.10	63.02	-11.53**	-19.58**	-15.12**	-19.78**
RFTS-1 (SHANT) × Krishnaprabha Bhari	62.44	63.44	68.06	8.13**	7.28**	-8.33**	-13.37**
RFTS-1 (SHANT) × Krishnaprabha Tunga		67.84	81.37	24.92**	19.94**	9.58**	3.58**
RFTS-1 (SHANT) × Krishnaprabha Shalmala		64.10	62.91	-0.57	-1.86**	-15.27**	-19.92**
Krishnaprabha Bhari × Krishnaprabha Tunga	63.44	67.84	73.43	11.87**	8.24**	-1.10	-6.53**
Krishnaprabha Bhari × Krishnaprabha Shalmala		64.10	59.30	-7.01**	-7.49**	-20.13**	-24.52**
Krishnaprabha Tunga × Krishnaprabha Shalmala	67.84	64.10	61.86	-6.23**	-8.81**	-16.68**	-21.26**
Arka Ananya (Check-1)	74.25						
LHT-DON (Check-2)	78.56						
S.Em ±				0.51	0.59	0.59	0.59
CD @5%				1.04	1.20	1.20	1.20
CD @1%				1.39	1.61	1.61	1.61

*significant at 5% **significant at 1%

Table 4: *Per se* performance and magnitude of heterosis for number of branches in tomato

Crosses	*Per se* value for number of branches			Heterosis (%) over			
	Female	Male	F_1	MP	BP	SC (1)	SC(2)
Manulaksmi × PKM-1	4.30	4.50	3.80	-13.64**	-15.56**	11.76**	0.00
Manulaksmi × Kashi Vishesh		3.70	3.70	-7.50**	-13.95**	8.82**	-2.63**
Manulaksmi × Kashi Adarsh		4.20	4.10	-3.53**	-4.65**	20.59**	7.89**
Manulaksmi × RFTS-1 (SHANT)		3.70	3.70	-7.50**	-13.95**	8.82**	-2.63**
Manulaksmi × Krishnaprabha Bhari		3.90	4.10	0.00	-4.65**	20.59**	7.89**
Manulaksmi × Krishnaprabha Tunga		4.00	3.90	-6.02**	-9.30**	14.71**	2.63**
Manulaksmi × Krishnaprabha Shalmala		4.20	4.40	3.53**	2.33**	29.41**	15.79**
PKM-1 × Kashi Vishesh	4.50	3.70	3.60	-12.20**	-20.00**	5.88**	-5.26**
PKM-1 × Kashi Adarsh		4.20	3.90	-10.34**	-13.33**	14.71**	2.63**
PKM-1 × RFTS-1 (SHANT)		3.70	3.70	-9.76**	-17.78**	8.82**	-2.63**
PKM-1 × Krishnaprabha Bhari		3.90	3.70	-11.90**	-17.78**	8.82**	-2.63**
PKM-1 × Krishnaprabha Tunga		4.00	3.80	-10.59**	-15.56**	11.76**	0.00
PKM-1 × Krishnaprabha Shalmala		4.20	3.80	-12.64**	-15.56**	11.76**	0.00
Kashi Vishesh × Kashi Adarsh	3.70	4.20	4.10	3.80**	-2.38**	20.59**	7.89**
Kashi Vishesh × RFTS-1 (SHANT)		3.70	3.80	2.70**	2.70**	11.76**	0.00
Kashi Vishesh × Krishnaprabha Bhari		3.90	3.70	-2.63**	-5.13**	8.82**	-2.63**
Kashi Vishesh × Krishnaprabha Tunga		4.00	3.80	-1.30*	-5.00**	11.76**	0.00
Kashi Vishesh × Krishnaprabha Shalmala		4.20	3.90	-1.27*	-7.14**	14.71**	2.63**
Kashi Adarsh × RFTS-1 (SHANT)	4.20	3.70	3.80	-3.80**	-9.52**	11.76**	0.00
Kashi Adarsh × Krishnaprabha Bhari		3.90	3.40	-16.05**	-19.05**	0.00	-10.53**
Kashi Adarsh × Krishnaprabha Tunga		4.00	4.00	-2.44**	-4.76**	17.65**	5.26**
Kashi Adarsh × Krishnaprabha Shalmala		4.20	4.00	-4.76**	-4.76**	17.65**	5.26**
RFTS-1 (SHANT) × Krishnaprabha Bhari	3.70	3.90	4.00	5.26**	2.56**	17.65**	5.26**
RFTS-1 (SHANT) × Krishnaprabha Tunga		4.00	4.00	3.90**	0.00	17.65**	5.26**
RFTS-1 (SHANT) × Krishnaprabha Shalmala		4.20	4.00	1.27*	-4.76**	17.65**	5.26**
Krishnaprabha Bhari × Krishnaprabha Tunga	3.90	4.00	3.90	-1.27*	-2.50**	14.71**	2.63**
Krishnaprabha Bhari × Krishnaprabha Shalmala		4.20	4.10	1.23*	-2.38**	20.59**	7.89**
Krishnaprabha Tunga × Krishnaprabha Shalmala	4.0	4.20	3.80	-7.32**	-9.52**	11.76**	0.00
Arka Ananya (Check-1)	3.40						
LHT-DON (Check-2)	3.80						
S.Em ±				0.51	0.59	0.59	
CD @5%				1.04	1.20	1.20	
CD @1%				1.39	1.61	1.61	

*significant at 5% **significant at 1%

Table 5: *Per se* performance and magnitude of heterosis for days to 50% flowering in tomato.

Crosses	*Per se* value for days to 50% flowering			Heterosis (%) over			
	Female	Male	F_1	MP	BP	SC (1)	SC (2)
Manulaksmi × PKM-1	28.50	30.50	32.50	10.17**	6.56**	6.56**	6.56**
Manulaksmi × Kashi Vishesh		30.50	31.00	5.08**	1.64**	1.64**	1.64**
Manulaksmi × Kashi Adarsh		32.00	31.00	2.48**	-3.13**	1.64**	1.64**
Manulaksmi × RFTS-1 (SHANT)		33.50	30.50	-1.61**	-8.96**	0.00	0.00
Manulaksmi × Krishnaprabha Bhari		31.50	31.00	3.33**	-1.59*	1.64**	1.64**
Manulaksmi × Krishnaprabha Tunga		30.00	30.50	4.27**	1.67**	0.00	0.00
Manulaksmi × Krishnaprabha Shalmala		28.50	32.50	14.04**	14.04**	6.56**	6.56**
PKM-1 × Kashi Vishesh	30.50	30.50	31.50	3.28**	3.28**	3.28**	3.28**
PKM-1 × Kashi Adarsh		32.00	29.00	-7.20**	-9.38**	-4.92**	-4.92**
PKM-1 × RFTS-1 (SHANT)		33.50	27.50	-14.06**	-17.91**	-9.84**	-9.84**
PKM-1 × Krishnaprabha Bhari		31.50	31.50	1.61**	0.00	3.28**	3.28**
PKM-1 × Krishnaprabha Tunga		30.00	30.50	0.83	0.00	0.00	0.00
PKM-1 × Krishnaprabha Shalmala		28.50	31.50	6.78**	3.28**	3.28**	3.28**
Kashi Vishesh × Kashi Adarsh	30.50	32.00	27.00	-13.60**	-15.63**	-11.48**	-11.48**
Kashi Vishesh × RFTS-1 (SHANT)		33.50	31.00	-3.13**	-7.46**	1.64**	1.64**
Kashi Vishesh × Krishnaprabha Bhari		31.50	27.50	-11.29**	-12.70**	-9.84**	-9.84**
Kashi Vishesh × Krishnaprabha Tunga		30.00	29.50	-2.48**	-3.28**	-3.28**	-3.28**
Kashi Vishesh × Krishnaprabha Shalmala		28.50	30.00	1.69**	-1.64**	-1.64**	-1.64**
Kashi Adarsh × RFTS-1 (SHANT)	32.00	33.50	29.50	-9.92**	-11.94**	-3.28**	-3.28**
Kashi Adarsh × Krishnaprabha Bhari		31.50	30.00	-5.51**	-6.25**	-1.64**	-1.64**
Kashi Adarsh × Krishnaprabha Tunga		30.00	31.50	1.61**	-1.56*	3.28**	3.28**
Kashi Adarsh × Krishnaprabha Shalmala		28.50	30.00	-0.83	-6.25**	-1.64**	-1.64**
RFTS-1 (SHANT) × Krishnaprabha Bhari	33.50	31.50	32.50	0.00	-2.99**	6.56**	6.56**
RFTS-1 (SHANT) × Krishnaprabha Tunga		30.00	31.00	-2.36**	-7.46**	1.64**	1.64**
RFTS-1 (SHANT) × Krishnaprabha Shalmala		28.50	31.00	0.00	-7.46**	1.64**	1.64**
Krishnaprabha Bhari × Krishnaprabha Tunga	31.50	30.00	28.50	-7.32**	-9.52**	-6.56**	-6.56**
Krishnaprabha Bhari × Krishnaprabha Shalmala		28.50	30.50	1.67**	-3.17**	0.00	0.00
Krishnaprabha Tunga × Krishnaprabha Shalmala	30.00	28.50	30.00	2.56**	0.00	-1.64**	-1.64**
Arka Ananya (Check-1)	30.50						
LHT-DON (Check-2)	30.50						
S.Em ±				0.51	0.59	0.59	0.59
CD @5%				1.01	1.20	1.20	1.20
CD @1%				1.39	1.61	1.61	1.61

*significant at 5% **significant at 1%

Table 6: *Per se* performance and magnitude of heterosis for fruit length (cm) in tomato.

Crosses	*Per se* value for fruit length (cm)			Heterosis (%) over			
	Female	Male	F_1	MP	BP	SC (1)	SC(2)
Manulaksmi × PKM-1	5.09	5.59	4.7	-11.98**	-15.92**	-18.69**	-31.39**
Manulaksmi × Kashi Vishesh		5.56	4.42	-16.99**	-20.50**	-23.53**	-35.47**
Manulaksmi × Kashi Adarsh		5.80	5.82	6.88**	0.34	0.69	-15.04**
Manulaksmi × RFTS-1 (SHANT)		4.90	5.68	13.71**	11.59**	-1.73**	-17.08**
Manulaksmi × Krishnaprabha Bhari		5.14	5.22	2.15**	1.65**	-9.69**	-23.80**
Manulaksmi × Krishnaprabha Tunga		6.08	5.25	-5.90**	-13.56**	-9.17**	-23.36**
Manulaksmi × Krishnaprabha Shalmala		5.55	5.59	5.16**	0.81	-3.29**	-18.39**
PKM-1 × Kashi Vishesh	5.59	5.56	5.67	1.79**	1.52*	-1.90**	-17.23**
PKM-1 × Kashi Adarsh		5.80	4.49	-21.07**	-22.5**	-22.32**	-34.45**
PKM-1 × RFTS-1 (SHANT)		4.90	5.56	6.10**	-0.44	-3.81**	-18.83**
PKM-1 × Krishnaprabha Bhari		5.14	5.63	4.93**	0.71	-2.60**	-17.81**
PKM-1 × Krishnaprabha Tunga		6.08	6.05	3.77**	-0.41	4.67**	-11.68**
PKM-1 × Krishnaprabha Shalmala		5.55	5.74	3.05**	2.68**	-0.69	-16.20**
Kashi Vishesh × Kashi Adarsh	5.56	5.80	6.31	11.09**	8.79**	9.17**	-7.88**
Kashi Vishesh × RFTS-1 (SHANT)		4.90	5.77	10.32**	3.77**	-0.17	-15.77**
Kashi Vishesh × Krishnaprabha Bhari		5.14	4.84	-9.43**	-12.85**	-16.26**	-29.34**
Kashi Vishesh × Krishnaprabha Tunga		6.08	5.91	1.54**	-2.79**	2.25**	-13.72**
Kashi Vishesh × Krishnaprabha Shalmala		5.55	5.72	3.06**	2.96**	-1.04	-16.50**
Kashi Adarsh × RFTS-1 (SHANT)	5.80	4.90	4.80	-10.18**	-17.15**	-16.96**	-29.93**
Kashi Adarsh × Krishnaprabha Bhari		5.14	4.9	-10.42**	-15.51**	-15.22**	-28.47**
Kashi Adarsh × Krishnaprabha Tunga		6.08	6.05	1.93**	-0.41	4.67**	-11.68**
Kashi Adarsh × Krishnaprabha Shalmala		5.55	5.18	-8.72**	-10.68**	-10.38**	-24.38**
RFTS-1 (SHANT) × Krishnaprabha Bhari	4.90	5.14	5.90	17.62**	14.88**	2.08**	-13.87**
RFTS-1 (SHANT) × Krishnaprabha Tunga		6.08	4.48	-18.39**	-26.31**	-22.49**	-34.60**
RFTS-1 (SHANT) × Krishnaprabha Shalmala		5.55	5.46	4.59**	-1.53*	-5.54**	-20.29**
Krishnaprabha Bhari × Krishnaprabha Tunga	5.14	6.08	4.95	-11.76**	-18.58**	-14.36**	-27.74**
Krishnaprabha Bhari × Krishnaprabha Shalmala		5.55	4.65	-12.90**	-16.12**	-19.55**	-32.12**
Krishnaprabha Tunga × Krishnaprabha Shalmala	6.08	5.55	5.98	2.92**	-1.56*	3.46**	-12.70**
Arka Ananya (Check-1)	5.78						
LHT-DON (Check-2)	6.85						
S.Em ±				0.51	0.59	0.59	0.59
CD @5%				1.04	1.20	1.20	1.20
CD @1%				1.39	1.61	1.61	1.61

*significant at 5% **significant at 1%

Table 7: Per se performance and magnitude of heterosis for fruit diameter (cm) in tomato.

Crosses	*Per se* value for fruit diameter (cm)			Heterosis (%) over			
	Female	Male	F_1	MP	BP	SC (1)	SC(2)
Manulaksmi × PKM-1	4.65	4.85	4.28	-9.89**	-11.75**	-17.21**	-2.06**
Manulaksmi × Kashi Vishesh		4.70	4.15	-11.12**	-11.59**	-19.63**	-5.03**
Manulaksmi × Kashi Adarsh		4.89	4.16	-12.68**	-14.82**	-19.43**	-4.81**
Manulaksmi × RFTS-1 (SHANT)		4.53	4.23	-7.73**	-8.92**	-18.08**	-3.20**
Manulaksmi × Krishnaprabha Bhari		4.69	4.13	-11.56**	-11.94**	-20.11**	-5.49**
Manulaksmi × Krishnaprabha Tunga		4.91	4.37	-8.57**	-10.99**	-15.47**	0.00
Manulaksmi × Krishnaprabha Shalmala		4.15	4.42	0.56	-4.83**	-14.41**	1.14**
PKM-1 × Kashi Vishesh	4.85	4.70	4.57	-4.29**	-5.77**	-11.60**	4.58**
PKM-1 × Kashi Adarsh		4.89	3.76	-22.68**	-23.00**	-27.17**	-13.96**
PKM-1 × RFTS-1 (SHANT)		4.53	4.58	-2.34**	-5.56**	-11.41**	4.81**
PKM-1 × Krishnaprabha Bhari		4.69	4.61	-3.35**	-4.94**	-10.83**	5.49**
PKM-1 × Krishnaprabha Tunga		4.91	4.27	-12.5**	-13.03**	-17.40**	-2.29**
PKM-1 × Krishnaprabha Shalmala		4.15	4.64	3.11**	-4.32**	-10.25**	6.18**
Kashi Vishesh × Kashi Adarsh	4.70	4.89	5.4	12.61**	10.42**	4.44**	23.57**
Kashi Vishesh × RFTS-1 (SHANT)		4.53	4.31	-6.60**	-8.29**	-16.63**	-1.37**
Kashi Vishesh × Krishnaprabha Bhari		4.69	5.26	12.14**	12.02**	1.83**	20.37**
Kashi Vishesh × Krishnaprabha Tunga		4.91	5.09	5.93**	3.66**	-1.54*	16.48**
Kashi Vishesh × Krishnaprabha Shalmala		4.15	4.14	-6.44**	-11.91**	-19.92**	-5.26**
Kashi Adarsh × RFTS-1 (SHANT)	4.89	4.53	5.00	6.26**	2.35**	-3.19**	14.42**
Kashi Adarsh × Krishnaprabha Bhari		4.69	5.54	15.76**	13.39**	7.25**	26.77**
Kashi Adarsh × Krishnaprabha Tunga		4.91	4.15	-15.30**	-15.47**	-19.72**	-5.03**
Kashi Adarsh × Krishnaprabha Shalmala		4.15	4.53	0.33	-7.25**	-12.28**	3.66**
RFTS-1 (SHANT) × Krishnaprabha Bhari	4.53	4.69	4.87	5.74**	3.94**	-5.70**	11.44**
RFTS-1 (SHANT) × Krishnaprabha Tunga		4.91	4.33	-8.15**	-11.71**	-16.15**	-0.92
RFTS-1 (SHANT) × Krishnaprabha Shalmala		4.15	4.87	12.21**	7.50**	-5.80**	11.44**
Krishnaprabha Bhari × Krishnaprabha Tunga	4.69	4.91	4.16	-13.22**	-15.17**	-19.43**	-4.81**
Krishnaprabha Bhari × Krishnaprabha Shalmala		4.15	5.17	17.08**	10.34**	0.09	18.31**
Krishnaprabha Tunga × Krishnaprabha Shalmala	4.91	4.15	4.65	2.75**	-5.19**	-9.96**	6.41**
Arka Ananya (Check-1)	5.17						
LHT-DON (Check-2)	4.37						
S.Em ±				0.51	0.59	0.59	0.59
CD @5%				1.04	1.20	1.20	1.20
CD @1%				1.39	1.61	1.61	1.61

*significant at 5% **significant at 1%

Table 8: *Per se* performance and magnitude of heterosis for number of locules in tomato.

Crosses	*Per se* value for number of locules			Heterosis (%) over			
	Female	Male	F1	MP	BP	SC (1)	SC(2)
Manulaksmi × PKM-1	4.7	3.40	4.00	-1.23*	-14.89**	-34.43**	0.00**
Manulaksmi × Kashi Vishesh		5.70	3.60	-30.77**	-36.84**	-40.98**	-10.00**
Manulaksmi × Kashi Adarsh		5.20	3.00	-39.39**	-42.31**	-50.82**	-25.00**
Manulaksmi × RFTS-1 (SHANT)		3.40	3.70	-8.64**	-21.28**	-39.34**	-7.50**
Manulaksmi × Krishnaprabha Bhari		6.00	5.80	8.41**	-3.33**	-4.92**	45.00**
Manulaksmi × Krishnaprabha Tunga		7.50	6.00	-1.64**	-20.00**	-1.64**	50.00**
Manulaksmi × Krishnaprabha Shalmala		6.40	3.67	22.52**	6.25**	-39.84**	-8.25**
PKM-1 × Kashi Vishesh	3.4	5.70	4.90	7.69**	-14.04**	-19.67**	22.50**
PKM-1 × Kashi Adarsh		5.20	3.70	-13.95**	-28.85**	-39.34**	-7.50**
PKM-1 × RFTS-1 (SHANT)		3.40	5.80	70.59**	70.59**	-4.92**	45.00**
PKM-1 × Krishnaprabha Bhari		6.00	6.80	44.68**	13.33**	11.48**	70.00**
PKM-1 × Krishnaprabha Tunga		7.50	2.60	-52.29**	-65.33**	-57.38**	-35.00**
PKM-1 × Krishnaprabha Shalmala		6.40	4.30	-12.24**	-32.81**	-29.51**	7.50**
Kashi Vishesh × Kashi Adarsh	5.7	5.20	4.90	-10.09**	-14.04**	-19.67**	22.50**
Kashi Vishesh × RFTS-1 (SHANT)		3.40	4.10	-9.89**	-28.07**	-32.79**	2.50**
Kashi Vishesh × Krishnaprabha Bhari		6.00	5.60	-4.27**	-6.67**	-8.20**	40.00**
Kashi Vishesh × Krishnaprabha Tunga		7.50	6.80	3.03**	-9.33**	11.48**	70.00**
Kashi Vishesh × Krishnaprabha Shalmala		6.40	3.00	-50.41**	-53.13**	-50.82**	-25.00**
Kashi Adarsh × RFTS-1 (SHANT)	5.2	3.40	3.90	-9.30**	-25.00**	-36.07**	-2.50**
Kashi Adarsh × Krishnaprabha Bhari		6.00	3.90	-30.36**	-35.00**	-36.07**	-2.50**
Kashi Adarsh × Krishnaprabha Tunga		7.50	5.80	-8.66**	-22.67**	-4.92**	45.00**
Kashi Adarsh × Krishnaprabha Shalmala		6.40	4.00	-31.03**	-37.50**	-34.43**	0.00
RFTS-1 (SHANT) × Krishnaprabha Bhari	3.4	6.00	3.20	-31.91**	-46.67**	-47.54**	-20.00**
RFTS-1 (SHANT) × Krishnaprabha Tunga		7.50	3.40	-37.61**	-54.67**	-44.26**	-15.00**
RFTS-1 (SHANT) × Krishnaprabha Shalmala		6.40	3.90	-20.41**	-39.06**	-36.07**	-2.50**
Krishnaprabha Bhari × Krishnaprabha Tunga	6.0	7.50	4.80	-28.89**	-36.00**	-21.31**	20.00**
Krishnaprabha Bhari × Krishnaprabha Shalmala		6.40	4.50	-27.42**	-29.69**	-26.23**	12.50**
Krishnaprabha Tunga × Krishnaprabha Shalmala	7.5	6.40	4.00	-42.45**	-46.67**	-34.43**	0.00
Arka Ananya (Check-1)	6.10						
LHT-DON (Check-2)	4.00						
S.Em ±				0.51	0.59	0.59	0.59
CD @5%				1.04	1.20	1.20	1.20
CD @1%				1.39	1.61	1.61	1.61

*significant at 5% **significant at 1%

Table 9: *Per se* performance and magnitude of heterosis for average fruit weight (g) in tomato.

Crosses	*Per se* value for average fruit weight (g)			Heterosis (%) over			
	Female	Male	F1	MP	BP	SC (1)	SC (2)
Manulaksmi × PKM-1	77.30	74.60	56.29	-25.89**	-27.18**	-38.36**	-37.00**
Manulaksmi × Kashi Vishesh		74.60	63.96	-13.51**	-17.26**	-29.96**	-28.42**
Manulaksmi × Kashi Adarsh		70.61	60.64	-24.50**	-27.23**	-33.60**	-32.13**
Manulaksmi × RFTS-1 (SHANT)		83.33	57.20	-23.73**	-26.00**	-37.36**	-35.98**
Manulaksmi × Krishnaprabha Bhari		72.70	55.93	-18.82**	-27.65**	-38.75**	-37.40**
Manulaksmi × Krishnaprabha Tunga		60.50	62.71	-23.22**	-27.12**	-31.33**	-29.82**
Manulaksmi × Krishnaprabha Shalmala		86.05	65.44	-8.49**	-15.34**	-28.34**	-26.76**
PKM-1 × Kashi Vishesh	74.60	74.60	57.90	-20.25**	-22.39**	-36.60**	-35.20**
PKM-1 × Kashi Adarsh		70.61	52.65	-33.32**	-36.82**	-42.35**	-41.07**
PKM-1 × RFTS-1 (SHANT)		83.33	89.85	22.00**	20.44**	-1.61**	0.56**
PKM-1 × Krishnaprabha Bhari		72.70	77.85	15.25**	4.36**	-14.75**	-12.87**
PKM-1 × Krishnaprabha Tunga		60.50	63.71	-20.68**	-25.96**	-30.23**	-28.70**
PKM-1 × Krishnaprabha Shalmala		86.05	79.71	13.61	6.85**	-12.71**	-10.79**
Kashi Vishesh × Kashi Adarsh	70.61	70.61	97.22	26.31**	16.67**	6.46**	8.81**
Kashi Vishesh × RFTS-1 (SHANT)		83.33	72.29	0.89**	-0.56**	-20.84**	-19.09**
Kashi Vishesh × Krishnaprabha Bhari		72.70	89.32	36.25**	26.50**	-2.19**	-0.03**
Kashi Vishesh × Krishnaprabha Tunga		60.50	84.01	7.25**	-2.37**	-8.00**	-5.98**
Kashi Vishesh × Krishnaprabha Shalmala		86.05	74.59	9.43**	5.64**	-18.32**	-16.52**
Kashi Adarsh × RFTS-1 (SHANT)	83.30	83.33	46.49	-40.41**	-44.21**	-49.09**	-47.97**
Kashi Adarsh × Krishnaprabha Bhari		72.70	70.19	-2.40**	-15.77**	-23.14**	-21.44**
Kashi Adarsh × Krishnaprabha Tunga		60.50	68.69	-18.89**	-20.17**	-24.78**	-23.12**
Kashi Adarsh × Krishnaprabha Shalmala		86.05	42.05	-43.58**	-49.54**	-53.95**	-52.94**
RFTS-1 (SHANT) × Krishnaprabha Bhari	72.70	72.70	71.35	7.13**	-1.86**	-21.87**	-20.15**
RFTS-1 (SHANT) × Krishnaprabha Tunga		60.50	60.84	-23.35**	-29.30**	-33.38**	-31.91**
RFTS-1 (SHANT) × Krishnaprabha Shalmala		86.05	52.95	-23.49**	-27.17**	-42.02**	-40.74**
Krishnaprabha Bhari × Krishnaprabha Tunga	60.50	60.50	64.96	-11.35**	-24.51**	-28.87**	-27.30**
Krishnaprabha Bhari × Krishnaprabha Shalmala		86.05	67.01	6.18**	1.96**	-26.62**	-25.00**
Krishnaprabha Tunga × Krishnaprabha Shalmala	86.50	86.05	52.95	-30.22**	-38.47**	-42.02**	-40.74**
Arka Ananya (Check-1)	91.32						
LHT-DON (Check-2)	89.35						
S.Em ±				0.51	0.59	0.59	0.59
CD @5%				1.04	1.20	12.99	12.99
CD @1%				1.39	1.20	1.61	1.61

*significant at 5% **significant at 1%

Table 10: *Per se* performance and magnitude of heterosis for lycopene content (mg/100 g) in tomato.

Crosses	*Per se* value for lycopene content (mg/100g)			Heterosis (%) over			
	Female	Male	F1	MP	BP	SC (1)	SC (2)
Manulaksmi × PKM-1	0.87	0.84	0.88	2.92**	1.15	-9.28**	-3.30**
Manulaksmi × Kashi Vishesh		0.74	0.78	-3.11**	-10.34**	-19.59**	-14.29**
Manulaksmi × Kashi Adarsh		0.75	0.80	-1.23*	-8.05**	-17.53**	-12.09**
Manulaksmi × RFTS-1 (SHANT)		0.79	0.83	0.00	-4.60**	-14.43**	-8.79**
Manulaksmi × Krishnaprabha Bhari		0.80	0.73	-12.57**	-16.09**	-24.74**	-19.78**
Manulaksmi × Krishnaprabha Tunga		0.79	0.74	-10.84**	-14.94**	-23.71**	-18.68**
Manulaksmi × Krishnaprabha Shalmala		0.79	0.84	1.20*	-3.45**	-13.40**	-7.69**
PKM-1 × Kashi Vishesh	0.84	0.74	0.73	-7.59**	-13.10**	-24.74**	-19.78**
PKM-1 × Kashi Adarsh		0.75	0.81	1.89**	-3.57**	-16.49**	-10.99**
PKM-1 × RFTS-1 (SHANT)		0.79	0.74	-9.20**	-11.90**	-23.71**	-18.68**
PKM-1 × Krishnaprabha Bhari		0.80	0.84	2.44**	0.00	-13.40**	-7.69**
PKM-1 × Krishnaprabha Tunga		0.79	0.84	3.07**	0.00	-13.40**	-7.69**
PKM-1 × Krishnaprabha Shalmala		0.79	0.79	-3.07**	-5.95**	-18.56**	-13.19**
Kashi Vishesh × Kashi Adarsh	0.74	0.75	0.86	15.44**	14.67**	-11.34**	-5.49**
Kashi Vishesh × RFTS-1 (SHANT)		0.79	0.80	4.58**	1.27*	-17.53**	-12.09**
Kashi Vishesh × Krishnaprabha Bhari		0.80	0.99	32.47**	27.50**	2.06**	8.79**
Kashi Vishesh × Krishnaprabha Tunga		0.79	0.84	9.80**	6.33**	-13.40**	-7.69**
Kashi Vishesh × Krishnaprabha Shalmala		0.79	0.87	13.73**	10.13**	-10.31**	-4.40**
Kashi Adarsh × RFTS-1 (SHANT)	0.75	0.79	0.79	2.60**	0.00	-18.56**	-13.19**
Kashi Adarsh × Krishnaprabha Bhari		0.80	0.82	5.81**	2.50**	-15.46**	-9.89**
Kashi Adarsh × Krishnaprabha Tunga		0.79	0.83	7.79**	5.06**	-14.43**	-8.79**
Kashi Adarsh × Krishnaprabha Shalmala		0.79	0.64	-16.88**	-18.99**	-34.02**	-29.67**
RFTS-1 (SHANT) × Krishnaprabha Bhari	0.79	0.80	0.73	-8.18**	-8.75**	-24.74**	-19.78**
RFTS-1 (SHANT) × Krishnaprabha Tunga		0.79	0.82	3.80**	3.80**	-15.46**	-9.89**
RFTS-1 (SHANT) × Krishnaprabha Shalmala		0.79	0.73	-7.59**	-7.59**	-24.74**	-19.78**
Krishnaprabha Bhari × Krishnaprabha Tunga	0.80	0.79	0.98	15.72**	15.00**	1.03	7.69**
Krishnaprabha Bhari × Krishnaprabha Shalmala		0.79	0.84	5.66**	5.00**	-13.40**	-7.69**
Krishnaprabha Tunga × Krishnaprabha Shalmala	0.79	0.79	0.82	3.80**	3.80**	-15.46**	-9.89**
Arka Ananya (Check-1)	0.97						
LHT-DON (Check-2)	0.91						
S.Em ±				0.51	0.59	0.59	0.59
CD @5%				1.04	1.20	1.20	1.20
CD @1%				1.39	1.61	1.61	1.61

*significant at 5% **significant at 1%

Table 11: *Per se* performance and magnitude of heterosis for ascorbic acid content (mg/100 g) in tomato.

Crosses	*Per se* value for ascorbic acid (mg/100g)			Heterosis (%) over			
	Female	Male	F1	MP	BP	SC (1)	SC(2)
Manulaksmi × PKM-1	25.60	25.36	29.22	14.54**	13.87**	-1.91**	20.59**
Manulaksmi × Kashi Vishesh		24.22	27.72	11.15**	8.03**	-6.95**	14.40**
Manulaksmi × Kashi Adarsh		25.68	25.79	0.47	0.43	-13.43**	6.44**
Manulaksmi × RFTS-1 (SHANT)		26.00	27.19	5.27**	4.58**	-8.73**	12.22**
Manulaksmi × Krishnaprabha Bhari		27.26	22.77	-13.95**	-16.47**	-23.56**	-6.03**
Manulaksmi × Krishnaprabha Tunga		29.79	26.89	-3.01**	-9.73**	-9.73**	10.98**
Manulaksmi × Krishnaprabha Shalmala		28.43	21.20	-21.61**	-25.43**	-28.84**	-12.51**
PKM-1 × Kashi Vishesh	25.36	24.22	24.61	-0.73	-2.96**	-17.39**	1.57**
PKM-1 × Kashi Adarsh		25.68	21.73	-14.85**	-15.38**	-27.06**	-10.32**
PKM-1 × RFTS-1 (SHANT)		26.00	29.05	13.12**	11.73**	-2.48**	19.89**
PKM-1 × Krishnaprabha Bhari		27.26	25.03	-4.87**	-8.18**	-15.98**	3.30**
PKM-1 × Krishnaprabha Tunga		29.79	25.74	-6.65**	-13.60**	-13.60**	6.23**
PKM-1 × Krishnaprabha Shalmala		28.43	24.24	-9.87**	-14.74**	-18.63**	0.04**
Kashi Vishesh × Kashi Adarsh	24.22	25.68	29.03	16.35**	13.05**	-2.55**	19.81**
Kashi Vishesh × RFTS-1 (SHANT)		26.00	25.27	0.64	-2.81**	-15.17**	4.29**
Kashi Vishesh × Krishnaprabha Bhari		27.26	30.33	17.83**	11.26**	1.81**	25.18**
Kashi Vishesh × Krishnaprabha Tunga		29.79	25.03	-7.31**	-15.98**	-15.98**	3.30**
Kashi Vishesh × Krishnaprabha Shalmala		28.43	23.22	-11.79**	-18.33**	-22.05**	-4.17**
Kashi Adarsh × RFTS-1 (SHANT)	25.68	26.00	25.45	-1.51**	-2.12**	-14.57**	5.04**
Kashi Adarsh × Krishnaprabha Bhari		27.26	22.77	-13.98**	-16.47**	-23.56**	-6.03**
Kashi Adarsh × Krishnaprabha Tunga		29.79	25.05	-9.68**	-15.91**	-15.91**	3.38**
Kashi Adarsh × Krishnaprabha Shalmala		28.43	21.20	-21.64**	-25.43**	-28.84**	-12.51**
RFTS-1 (SHANT) × Krishnaprabha Bhari	26.00	27.26	29.90	12.28**	9.68**	0.37**	23.40**
RFTS-1 (SHANT) × Krishnaprabha Tunga		29.79	29.95	7.37**	0.54	0.54**	23.61**
RFTS-1 (SHANT) × Krishnaprabha Shalmala		28.43	27.15	-0.24	-4.50**	-8.86**	12.05**
Krishnaprabha Bhari × Krishnaprabha Tunga	27.26	29.79	29.63	3.87**	-0.54	-0.54**	22.29**
Krishnaprabha Bhari × Krishnaprabha Shalmala		28.43	29.12	4.58**	2.43**	-2.25**	20.18**
Krishnaprabha Tunga × Krishnaprabha Shalmala	29.79	28.43	29.29	0.62	-1.68**	-1.68**	20.88**
Arka Ananya (Check-1)	29.79						
LHT-DON (Check-2)	24.23						
S.Em ±				0.51	0.59	0.59	0.59
CD @5%				1.04	1.20	1.20	1.20
CD @1%				1.39	1.61	1.61	1.61

*significant at 5% **significant at 1%

Table 12: *Per se* performance and magnitude of heterosis for TSS (°Brix) in tomato.

Crosses	*Per se* value for TSS (°Brix)			Heterosis (%) over			
	Female	Male	F1	MP	BP	SC (1)	SC (2)
Manulaksmi × PKM-1	4.55	4.52	4.64	2.32**	1.98**	-0.21**	2.65**
Manulaksmi × Kashi Vishesh		5.11	4.68	-3.11**	-8.41**	0.64**	3.54**
Manulaksmi × Kashi Adarsh		4.37	4.65	4.26**	2.20**	0.00	2.88**
Manulaksmi × RFTS-1 (SHANT)		4.46	4.65	3.22**	2.20**	0.00	2.88**
Manulaksmi × Krishnaprabha Bhari		4.35	4.53	1.80**	-0.44	-2.58**	0.22**
Manulaksmi × Krishnaprabha Tunga		4.58	3.67	-19.61**	-19.87**	-21.07**	-18.81**
Manulaksmi × Krishnaprabha Shalmala		5.14	5.28	8.98**	2.72**	13.54**	16.81**
PKM-1 × Kashi Vishesh	4.52	5.11	4.58	-4.88**	-10.37**	-1.50*	1.33**
PKM-1 × Kashi Adarsh		4.37	4.47	0.56	-1.11	-3.87**	-1.11**
PKM-1 × RFTS-1 (SHANT)		4.46	5.22	16.26**	15.49**	12.25**	15.49**
PKM-1 × Krishnaprabha Bhari		4.35	5.11	15.22**	13.05**	9.89**	13.05**
PKM-1 × Krishnaprabha Tunga		4.58	5.13	12.75**	12.01**	10.32**	13.50**
PKM-1 × Krishnaprabha Shalmala		5.14	3.58	-25.88**	-30.35**	-23.01**	-20.80**
Kashi Vishesh × Kashi Adarsh	5.11	4.37	5.23	10.34**	2.35**	12.47**	15.71**
Kashi Vishesh × RFTS-1 (SHANT)		4.46	5.29	10.55**	3.52**	13.76**	17.04**
Kashi Vishesh × Krishnaprabha Bhari		4.35	5.47	15.64**	7.05**	17.63**	21.02**
Kashi Vishesh × Krishnaprabha Tunga		4.58	3.61	-25.49**	-29.35**	-22.36**	-20.13**
Kashi Vishesh × Krishnaprabha Shalmala		5.14	4.58	-10.63**	-10.89**	-1.50*	1.33**
Kashi Adarsh × RFTS-1 (SHANT)	4.37	4.46	3.46	-21.63**	-22.42**	-25.59**	-23.45**
Kashi Adarsh × Krishnaprabha Bhari		4.35	4.33	-0.69	-0.92**	-6.88**	-4.20**
Kashi Adarsh × Krishnaprabha Tunga		4.58	3.92	-12.40**	-14.41	-15.69**	-13.27**
Kashi Adarsh × Krishnaprabha Shalmala		5.14	3.72	-21.77**	-27.63**	-20***	-17.70**
RFTS-1 (SHANT) × Krishnaprabha Bhari	4.46	4.35	3.77	-14.42**	-15.47**	-18.92**	-16.59**
RFTS-1 (SHANT) × Krishnaprabha Tunga		4.58	4.26	-5.75**	-6.99**	-8.38**	-5.75**
RFTS-1 (SHANT) × Krishnaprabha Shalmala		5.14	4.40	-8.33**	-14.40**	-5.37**	-2.65**
Krishnaprabha Bhari × Krishnaprabha Tunga	4.35	4.58	4.40	-1.46	-3.93**	-5.37***	-2.65**
Krishnaprabha Bhari × Krishnaprabha Shalmala		5.14	4.47	-5.80	-13.04**	-3.87**	-1.11
Krishnaprabha Tunga × Krishnaprabha Shalmala	4.58	5.14	3.92	-19.34**	-23.74**	-15.69**	-13.27**
Arka Ananya (Check-1)	4.65						
LHT-DON (Check-2)	4.52						
S.Em ±				0.51	0.59	0.59	0.59
CD @5%				1.04	1.20	1.20	1.20
CD @1%				1.39	1.61	1.61	1.61

*significant at 5% **significant at 1%

Table 13: *Per se* performance and magnitude of heterosis for shelf life (days) in tomato.

Crosses	*Per se* value for shelf life (days)			Heterosis (%) over			
	Female	Male	F1	MP	BP	SC (1)	SC (2)
Manulaksmi × PKM-1	6.5	7.00	7.00	3.70**	0.00	-17.65**	-26.32**
Manulaksmi × Kashi Vishesh		5.50	6.50	8.33**	0.00	-23.53**	-31.58**
Manulaksmi × Kashi Adarsh		5.00	7.00	21.74**	7.69**	-17.65**	-26.32**
Manulaksmi × RFTS-1 (SHANT)		5.50	6.50	8.33**	0.00	-23.53**	-31.58**
Manulaksmi × Krishnaprabha Bhari		5.00	7.00	21.74**	7.69**	-17.65**	-26.32**
Manulaksmi × Krishnaprabha Tunga		6.00	6.50	4.00**	0.00	-23.53**	-31.58**
Manulaksmi × Krishnaprabha Shalmala		6.00	6.50	4.00**	0.00	-23.53**	-31.58**
PKM-1 × Kashi Vishesh	7.0	5.50	7.00	12.00**	0.00	-17.65**	-26.32**
PKM-1 × Kashi Adarsh		5.00	5.50	-8.33**	-21.43**	-35.29**	-42.11**
PKM-1 × RFTS-1 (SHANT)		5.50	7.00	12.00**	0.00	-17.65**	-26.32**
PKM-1 × Krishnaprabha Bhari		5.00	6.50	8.33**	-7.14**	-23.53**	-31.58**
PKM-1 × Krishnaprabha Tunga		6.00	7.00	7.69**	0.00	-17.65**	-26.32**
PKM-1 × Krishnaprabha Shalmala		6.00	7.00	7.69**	0.00	-17.65**	-26.32**
Kashi Vishesh × Kashi Adarsh	5.5	5.00	9.50	42.86**	36.36**	11.76**	0.00
Kashi Vishesh × RFTS-1 (SHANT)		5.50	5.50	0.00	0.00	-35.29**	-42.11**
Kashi Vishesh × Krishnaprabha Bhari		5.00	9.00	23.81**	18.18**	5.88**	-5.26**
Kashi Vishesh × Krishnaprabha Tunga		6.00	6.00	4.35**	0.00	-29.41**	-36.84**
Kashi Vishesh × Krishnaprabha Shalmala		6.00	6.50	13.04**	8.33**	-23.53**	-31.58**
Kashi Adarsh × RFTS-1 (SHANT)	5.0	5.50	5.50	4.76**	0.00	-35.29**	-42.11**
Kashi Adarsh × Krishnaprabha Bhari		5.00	6.50	30.00**	30.00**	-23.53**	-31.58**
Kashi Adarsh × Krishnaprabha Tunga		6.00	6.56	19.27**	9.33**	-22.82**	-30.95**
Kashi Adarsh × Krishnaprabha Shalmala		6.00	7.50	36.36**	25.00**	-11.76**	-21.05**
RFTS-1 (SHANT) × Krishnaprabha Bhari	5.5	5.00	6.00	14.29**	9.09**	-29.41**	-36.84**
RFTS-1 (SHANT) × Krishnaprabha Tunga		6.00	5.50	-4.35**	-8.33**	-35.29**	-42.11**
RFTS-1 (SHANT) × Krishnaprabha Shalmala		6.00	6.50	13.04**	8.33**	-23.53**	-31.58**
Krishnaprabha Bhari × Krishnaprabha Tunga	5.0	6.00	5.00	-9.09**	-16.67**	-41.18**	-47.37**
Krishnaprabha Bhari × Krishnaprabha Shalmala		6.00	7.00	27.27**	16.67**	-17.65**	-26.32**
Krishnaprabha Tunga × Krishnaprabha Shalmala	6.0	6.00	5.50	-8.33**	-8.33**	-35.29**	-42.11**
Arka Ananya (Check-1)	8.50						
LHT-DON (Check-2)	9.50						
S.Em ±				0.51	0.59	0.59	0.59
CD @5%				1.04	1.20	1.20	1.20
CD @1%				1.40	1.61	1.61	1.61

*significant at 5% **significant at 1%

Table 14: *Per se* performance and magnitude of heterosis for fruit yield (t/ha) in tomato.

Crosses	*Per se* value for fruit yield (t/ha)			Heterosis (%) over			
	Female	Male	F1	MP	BP	SC (1)	SC (2)
Manulaksmi × PKM-1	70.30	70.85	71.59	1.44**	1.04	-14.26**	-11.62**
Manulaksmi × Kashi Vishesh		71.41	76.40	7.83**	6.99**	-8.50**	-5.68**
Manulaksmi × Kashi Adarsh		69.19	78.07	11.94**	11.05**	-6.50**	-3.62**
Manulaksmi × RFTS-1 (SHANT)		72.52	78.25	9.58**	7.90***	-6.29**	-3.40**
Manulaksmi × Krishnaprabha Bhari		76.40	69.56	-5.17**	-8.95**	-16.69**	-14.12**
Manulaksmi × Krishnaprabha Tunga		73.24	77.33	7.75**	5.58**	-7.39**	-4.53**
Manulaksmi × Krishnaprabha Shalmala		69.93	75.66	7.91**	7.62**	-9.39**	-6.59**
PKM-1 × Kashi Vishesh	70.85	71.41	77.33	8.72**	8.29**	-7.39**	-4.53**
PKM-1 × Kashi Adarsh		69.19	73.08	4.37	3.15**	-12.48**	-9.78**
PKM-1 × RFTS-1 (SHANT)		72.52	71.22	-0.65**	-1.79**	-14.71**	-12.07**
PKM-1 × Krishnaprabha Bhari		76.40	70.48	-4.27**	-7.75**	-15.59**	-12.99**
PKM-1 × Krishnaprabha Tunga		73.24	74.55	3.48**	1.79**	-10.72**	-7.96**
PKM-1 × Krishnaprabha Shalmala		69.93	71.90	2.23**	1.57*	-13.89**	-11.23**
Kashi Vishesh × Kashi Adarsh	71.41	69.19	85.71	21.92**	20.03**	2.65**	5.81**
Kashi Vishesh × RFTS-1 (SHANT)		72.52	73.81	2.56**	1.78**	-11.60**	-8.88**
Kashi Vishesh × Krishnaprabha Bhari		76.40	77.70	5.13**	1.70**	-6.95**	-4.07**
Kashi Vishesh × Krishnaprabha Tunga		73.24	74.37	2.83**	1.54*	-10.93**	-8.19**
Kashi Vishesh × Krishnaprabha Shalmala		69.93	79.92	13.09	11.92**	-4.29**	-1.33*
Kashi Adarsh × RFTS-1 (SHANT)	69.19	72.52	70.48	-0.53**	-2.81**	-15.59**	-12.99**
Kashi Adarsh × Krishnaprabha Bhari		76.40	81.40	11.82**	6.54**	-2.51**	0.49
Kashi Adarsh × Krishnaprabha Tunga		73.24	82.51	15.86**	12.66**	-1.19**	1.86**
Kashi Adarsh × Krishnaprabha Shalmala		69.93	81.58	17.28**	16.66**	-2.30**	0.72
RFTS-1 (SHANT) × Krishnaprabha Bhari	72.52	76.40	76.40	2.61**	0.00	-8.50**	-5.68**
RFTS-1 (SHANT) × Krishnaprabha Tunga		73.24	75.85	4.08**	3.56**	-9.16**	-6.36**
RFTS-1 (SHANT) × Krishnaprabha Shalmala		69.93	81.58	14.54**	12.49**	-2.30**	0.72
Krishnaprabha Bhari × Krishnaprabha Tunga	76.40	73.24	82.51	10.28**	8.00**	-1.19**	1.86**
Krishnaprabha Bhari × Krishnaprabha Shalmala		69.93	79.36	8.47**	3.87**	-4.96**	-2.02**
Krishnaprabha Tunga × Krishnaprabha Shalmala	73.24	69.93	77.70	8.54**	6.09**	-6.95**	-4.07**
Arka Ananya (Check-1)	83.50						
LHT-DON (Check-2)	81.00						
S.Em ±				0.51	0.59	0.59	0.59
CD @5%				1.04	1.20	1.20	1.20
CD @1%				1.39	1.61	1.61	1.61

*significant at 5% **significant at 1%

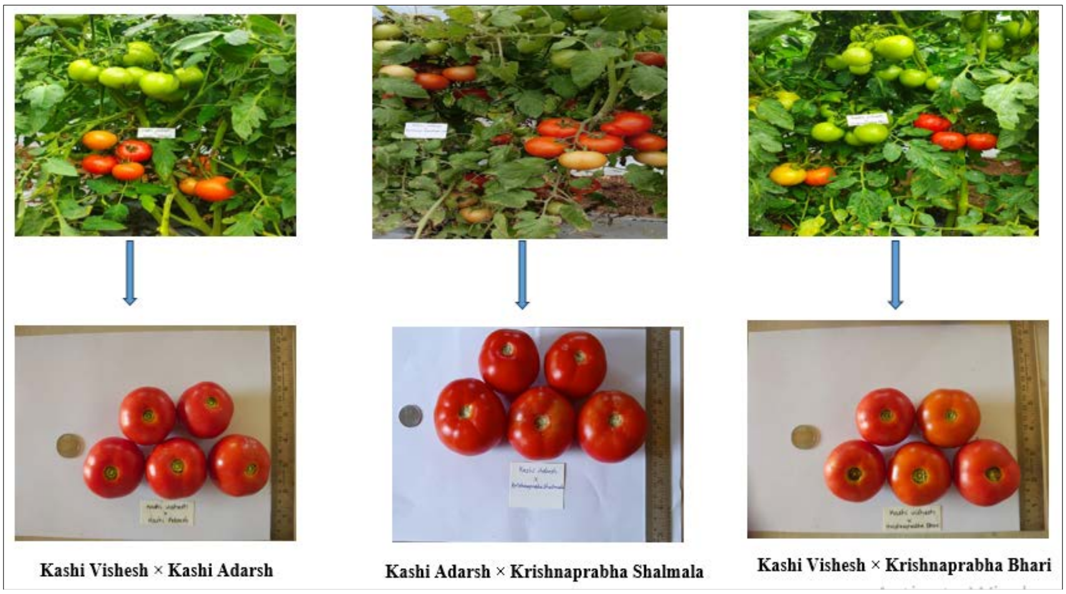


Plate 3: Better performing Hybrids

Conclusion

The results of the present study demonstrate that heterosis can be effectively exploited to achieve yield and quality improvement in tomato. The substantial positive heterosis observed for yield, average fruit weight, fruit diameter, and quality parameters like lycopene and ascorbic acid indicates the predominance of non-additive gene action. The hybrids Kashi Vishesh × Kashi Adarsh, Kashi Adarsh × Krishnaprabha Shalmala, and Kashi Vishesh × Krishnaprabha Bhari emerged as promising crosses for both yield and quality traits. These combinations should be further evaluated across multiple environments for stability and commercial potential. The study thus reaffirms that heterosis breeding remains one of the most powerful and dependable approaches for the genetic improvement of tomato productivity and quality.

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