RESEARCH ARTICLE Indian Journal of Agricultural Research, Volume 60 Issue 9: 1357-1363 (September 2026)

Impact on Growth, Yield and Diseases Incidence of Tomato (*Solanum lycopersicum* L.) Hybrid Arka Samrat under Front Line Demonstration

M. Adinarayana[1], E. Ravi Goud[1], G. Dhanalakshmi[1], D. Balaraju[1], P. Vishnu Mohana Reddy[1], J.V. Prasad[2]

10.18805/IJARe.A-6539

ABSTRACT

Background: Majority of the farmers in Kurnool district of Andhra Pradesh cultivate commercial hybrids which were low yielding and susceptible to pests and diseases. In this situation, introduction of high yielding hybrids with resistant to pest and diseases (Arka Samrat) were necessary to enhance productivityand to reduce cost of cultivation.

Methods: KVK, Yagantipalle were conducted frontline demonstrations (FLDs) during 2020-2022 in Kurnool district, Andhra Pradesh, to evaluate the performance of the IIHR hybrid Arka Samrat against the widely grown farmer's hybrid PHS 448. Experimental research design was used, total of 30 farmers selected purposively from Kurnool district in whose FLD plots were conducted along with control plot was taken into consideration for the study to evaluate the impact of growth, yield and diseases in tomato triple disease resistant hybrid of Arka Samrat.

Result: Results revealed that Arka Samrat consistently better performed over PHS 448, recorded higher fruit yield/plant (47.9 vs 29.3), yield/plant (4.43 vs 2.01 kg) and yield/ha (66.4 vs 40.2 t/ha). MANOVA confirmed, highly significant hybrid effect (Wilks' λ = 0.019, $p<0.001$), with fruits per cluster and plant height emerged as key determinants of productivity. Diseases in Arka Samrat had a significantly lower incidence of Early Blight (6.35%), TLCV (3.99%) and BW (2.59%) compared to PHS 448, with 63-83% of reduction. Study results revealed strong hybrid effects, fruits per cluster and plant height as key yield determinants. Also higher yield efficiency and disease tolerance make Arka Samrat a promising hybrid for cultivation under agro-climatic conditions of the Kurnool district, Andhra Pradesh.

Key words: Arka Samrat, Front line demonstration, MANOVA, Triple disease resistant.

INTRODUCTION

Tomato (*Solanum lycopersicum.* L) is popular and the major vegetables under cultivation after potato and belongs to family solanaceae (Kumar *et al.*, 2013). India ranks second in tomato production after China with 19.75 million tones accounting for worlds 10% share in production (NHB, 2020). Tomato is one of the major vegetable crops in the state of Andhra Pradesh, which is grown on 0.61 lakh hectares of l and year-round in a different agro climatic conditions with an average productivity of 46 t/ha. Tomato is important commercial crop grown by both marginal and commercial growers for a fresh market and processing industry. Among tomato cultivars, hybrids have significantly brought the revolution in tomato cultivation. Tomato hybrids excelled in yield but for the tolerance to diseases, high adaptability to adverse environment, uniformity of produce and greater plant vigour but also have shown great potential to counter the challenge of high dem and of fresh and processed products (Dhillon, 2019). There have been reports of a 300 per cent increase in total tomato yield compared to the commercial variety (Dhaliwal, 1986). Development of hybrid tomato varieties having desirable characters has proven to be an effective strategy to increase tomato production (Islam *et al.*, 2012). Recent studies have confirmed that exploitation of heterosis in tomato significantly enhances yield and quality traits, making hybrid development one of the most effective approaches for increasing tomato productivity. Positive heterosis for fruit yield, number of fruits per plant, fruit set and quality parameters has been widely reported under tropical and arid conditions (Alsadon *et al.,* 2021; Nayana *et al.,* 2024).

In Andhra Pradesh, tomato leaf curl virus (ToLCV), bacterial wilt (BW) and tomato early blight have been identified as the most destructive diseases. These

[1]ICAR-SHE and CS, Krishi Vigyan Kendra, Yagantipalle, Nandyal-518 124, Andhra Pradesh, India.
[2]ICAR-Agricultural Technology Application Research Institute, Zone-X, Hyderabad-500 059, Telangana, India.

Corresponding Author: M. Adinarayana, ICAR-SHE and CS, Krishi Vigyan Kendra, Yagantipalle, Nandyal-518 124, Andhra Pradesh, India. Email: adihorti007@gmail.com

ORCID: https://orcid.org/0009-0002-5258-4119

How to cite this article: Adinarayana, M., Goud, E.R., Dhanalakshmi, G., Balaraju, D., Reddy, P.V.M. and Prasad, J.V. (2026). Impact on Growth, Yield and Diseases Incidence of Tomato (*Solanum lycopersicum* L.) Hybrid Arka Samrat under Front Line Demonstration. *Indian Journal of Agricultural Research*. **60(9):** 1357-1363. doi: 10.18805/IJARe.A-6539.

Submitted: 16-03-2026 **Accepted:** 02-07-2026 **Online:** 29-07-2026

diseases all thrive in soil as well as in collateral and alternative host plants. The farming methods that farmers employ and the predominance of long-term favorable conditions are the main causes of these diseases flare-ups. Numerous approaches to treating these diseases have been developed, but many of them are site-specific or constrained by socioeconomic circumstances. Even while host resistance is the best method of control, it can be challenging to find cultivars with long-lasting resistance in different areas due to high humidity and temperature in tropical and subtropical regions. Also breeding for resistance for more than one disease is quite difficult and time consuming. Some of problems that farmers face with tomato growing area include the lack of knowledge on improved pest and disease-resistant tomato hybrids, the use of poor seed, low soil fertility, disease and insect pests (Mishra *et al.*, 2019).

However, there are varieties and hybrids in tomato which are stable in reacting as multiple resistant to the major diseases (Mishra *et al.*, 2019). Large number of high yielding tomato hybrids has been released for cultivation in open field cultivation (Kaddi *et al.*, 2014; Saravanan *et al.,* 2019).

There is an acute requirement in the district to introduce high yielding and disease resistant tomato hybrids. Accordingly, hybrids developed by the IIHR, Bengalur, were demonstrated under the agro-climatic conditions of the Kurnool district, Andhra Pradesh. The study was evaluated the hybrid productivity, disease resistant and suitability for cultivation in the region.

MATERIALS AND METHODS

The Krishi Vigyan Kendra, Yagantipalle, conducted 30 FLDs under actual farming conditions in five different villages located over three blocks *i.e.* Banaganapalli, Bethamcherla and Dhone of Kurnool district during *kharif* and *rabi* from 2020 to 2022. In order to find out the effects of growth, yield and disease control in tomato hybrid of Arka Samrat, an experimental research design with paired plot layout was used and selected thirty farmers purposively in whose FLD plots were conducted along with a control plot. Each demonstration covered an area of 0.4 ha from each location, with 0.4 ha of demo and control plots.

In the district red soil was used by farmers to cultivate tomatoes under irrigation.

For FLD used Arka Samrat hybrid which is crossing of IIHR-2835 × IIHR-2832, F1 hybrid with triple disease resistance to bacterial wilt (BW), early blight and tomato leaf curl disease (ToLCV). Arka Samrat tomato hybrids are huge (90-110 g), firm, deep red and oblate to high round. The Indian Institute of Horticulture Research (IIHR) provided the tomato Arka Samrat seed for FLDs. In the vegetable nursery unit of KVK Yagantipalle seed was sowed during the first week of June and made available to the farmers for transplantation. The seedlings were transplanted in farmer's fields during the first week of July 2020-2021, 2021-2022 and 2022-2023. For this demonstration, Arka Samrat and local check (PHS-448) were used. The seedlings were transplanted at a spacing of 90 × 45 cm when they were 25-30 days old. When the l and was being prepared, FYM @20 t/ha was added to the soil. At the time of transplanting, NPK 150:60:60 kg/ha was applied along with a half dose of nitrogen and a full dose of phosphorous and potash. The remaining half of the nitrogen was applied in two equal splits, at 30 and 60 days after transplanting, in a ring of 15 cm around the plant.

For better yields, two sprayings of micronutrient mixture (Arka Vegetable Special) were also applied 30 and 60 days after transplanting. Sticky traps in the colors yellow and blue, each with 25 numbers per hectare, were placed in the field. There were need based plant protection measures taken for both check and demo plots to observe the diseases incidence. Early blight, bacterial wilt (BW), tomato leaf curl virus (ToLCV) and late blight disease occurrences were noted. In the check and trial plots, the yield was collected from five locations each with a 10 m^2 area four times, or from four pickings and the data was converted to a per-ha basis. Also recorded the fruit's weight, number of fruits per plant, number of days till the first harvest. From each check and trial plot, economic parameters such as gross cost, net return and B:C ratio were calculated for comparison. Parameters like plant height (cm), number of fruits per plant, average fruit weight (g), average fruit diameter (cm), yield per plant (kg), yield per ha (t/ha), net income (Rs./ha), B:C ratio and market preference have been noted. The analysis of the data followed as per Panse and Sukhatme (1967). Data from three years of observations on growth, yield characteristics and economics on FLDs and indigenous adopted practices were collected and pooled. The pooled data were compared and statically analyzed.

Observations recorded

Observations on five randomly selected plants in each replication were recorded for various growth, yield and quality attributing traits to understand the performance of tomato hybrids. Incidence of bacterial wilt was recorded as and when wilt was observed and per cent wilt incidence (PWI) was calculated. Based on the per cent wilt incidence single cross hybrids were categorized into four groups as suggested by Mew and Ho (1976) *i.e.* 0-20: Resistant; 20-40: Moderately resistant; 40-60: Moderately susceptible; 60-100: Susceptible. Tomato leaf curl virus (ToLCV) incidence and severity: Based on the per cent of curling and puckering of leaves, the plants were scored using 0-4 scale as suggested by Banerjee and Kalloo (1987) *i.e.* 0: Symptoms absent; 1: Very mild curling (Upto 25% leaves); 2: Curling and puckering of 26-50% leaves; 3: Curling and puckering of 51-75% leaves and 4: Severe curling and puckering of >75% leaves. Based on the disease score,

per cent disease severity (PDS) was calculated using the following formula:

Per cent disease severity =

$$\frac{\text{Some of numerical rating}}{\text{Total no. of plants observed} \times \text{Maximum disease grade}} \times 100$$

Multivariate analysis of variance (MANOVA)

To examine the combined effect of hybrid and covariates on multiple yield-contributing traits, a Multivariate Analysis of Variance (MANOVA) was employed. Unlike univariate ANOVA, which analyzes traits individually, MANOVA simultaneously evaluates group differences across a set of correlated dependent variables, thereby increasing statistical power and reducing the risk of Type I error.

Here, Wilks' Lambda was used as the primary multivariate test statistic, supplemented by Pillai's Trace, Hotelling-Lawley Trace and Roy's Largest Root to ensure robustness of inference. Partial Eta^2 values were computed as measures of effect size, indicating the proportion of variance explained by each factor. This approach allowed identification of the most influential covariates while assessing overall hybrid performance across multiple traits (Tabachnick and Fidell, 2013; Hair *et al.,* 2019).

RESULTS AND DISCUSSION

Yield performance of tomato hybrids

The General Linear Model analysis (Table 1) revealed significant difference between the two tomato hybrids for yield contributing traits. Arka Samrat consistently outperformed PHS 448, producing a greater number of fruits per plant (47.9 vs 29.3), higher average fruit weight (92.5 g vs 68.3 g) and superior yield both per plant (4.43 vs 2.01 kg) and per hectare (66.4 vs 40.2 t/ha) (Fig 1).

Table 1: Statistical characterization of yield and yield-contributing traits in tomato hybrids.

Trait	Arka Samrat (Mean±SD)	PHS 448 (Mean±SD)	Overall mean
Fruit length (cm)	6.16±0.30	4.68±0.46	5.42
Fruit girth (cm)	5.44±0.39	4.25±0.37	4.84
Fruits per plant	47.87±7.21	29.32±3.12	38.60
Avg. fruit weight (g)	92.49±5.80	68.25±5.46	80.37
Yield per plant (kg)	4.43±0.75	2.01±0.29	3.22
Yield per ha (t/ha)	66.43±11.27	40.16±5.91	53.30

These results demonstrate the higher productive potential of Arka Samrat under the prevailing agro-climatic conditions. These results are line with the findings of Babu *et al.* (2023); Remzeena *et al.* (2023).

Multivariate analysis (MANOVA) of traits

The multivariate test (MANOVA) further confirmed a highly significant hybrid effect (Wilks' $\lambda = 0.019$, $F = 266.5$, $p<0.001$, Partial Eta^2 = 0.981), suggesting that strong discrimination between the two hybrids across yield traits (Table 2). Among the covariates, fruits per cluster contributed most significantly to yield variation ($p < 0.001$, Partial Eta^2 = 0.712), This agrees with the findings of Singh *et al.* (2017), who reported fruits per cluster as the most decisive determinant of yield potential in tomato hybrids. Sharma *et al.* (2021) also observed strong positive direct effects of fruits per cluster and number of fruits per plant on tomato yield.

Followed by plant height, which also influenced yield significantly ($p<0.05$), though its contribution was comparatively smaller (Partial Eta^2= 0.195). Similar moderate effects of plant height on yield traits have been documented by Kumar *et al.* (2018) and Nkansah *et al.* (2021).

Days to 50% flowering had a moderate but significant influence on average fruit weight ($p= 0.025$), While, fruit length did not significantly contribute to yield variation ($p>0.05$), aligning with reports that size-related traits do not always translate into higher productivity (Reddy *et al.,* 2016).

Fig 2, clearly shows that Hybrid (Arka Samrat vs PHS-448) (Partial Eta^2= 0.98, ***) and Fruits per cluster (0.71, ***) had the strongest effects on yield-related traits. Plant height (0.20, ns) and days to 50% flowering (0.30, ns) had moderate but non-significant effects, while fruit length had minimal influence (0.15, ns).

Univariate ANOVA for yield traits

The univariate tests of significance (Table 3) supported the MANOVA findings. Significant hybrid differences were observed for fruits per plant ($p= 0.012$) and yield per plant ($p=0.008$). Although Arka Samrat showed higher mean values for average fruit weight and yield per hectare, these differences were not statistically significant at the 5% level. Among covariates, fruits per cluster consistently influenced yield parameters at $p<0.001$, while plant height was also a significant predictor for fruits/plant, yield/ plant and yield/ hectare. The overall model explained a high proportion of

Table 2: Multivariate test of significance (MANOVA) for hybrid and covariates.

Effect	Wilks' Lambda	F-value	df (Hyp, Err)	Sig.	Partial Eta^2
Intercept	0.063	77.48	4, 21	0.001	0.937
Plant height	0.805	1.28	4, 21	0.311	0.195
Days to 50% flowering	0.696	2.30	4, 21	0.093	0.304
Fruits per cluster	0.288	12.95	4, 21	0.000	0.712
Fruit length	0.851	0.92	4, 21	0.470	0.149
Hybrid (Arka vs PHS)	0.019	266.5	4, 21	0.001	0.981

Table 3: Tests of Between-subjects effects (Univariate ANOVA) for tomato yield and yield-contributing traits.

Source	Fruits/plant (p)	Avg. fruit wt (p)	Yield/plant (p)	Yield /ha (p)
Hybrid	0.012*	0.094	0.008*	0.131
Plant height	0.044*	0.471	0.037*	0.032*
Days to 50% flowering	0.725	0.025*	0.065	0.077
Fruits per cluster	0.001**	0.220	0.001**	0.001**
Fruit length	0.694	0.329	0.525	0.673

*Significant values at (p<0.05); **Significant at p<0.001.

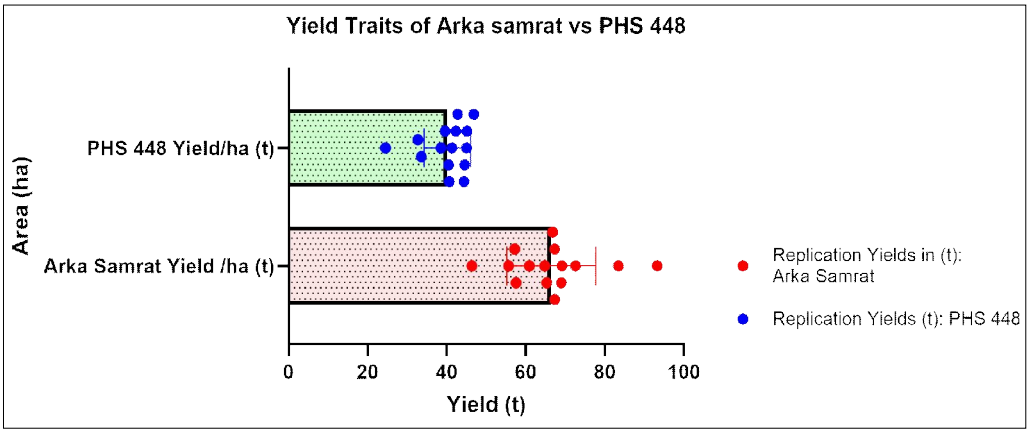

Fig 1: Yield comparison between Demo VS Farmers practice.

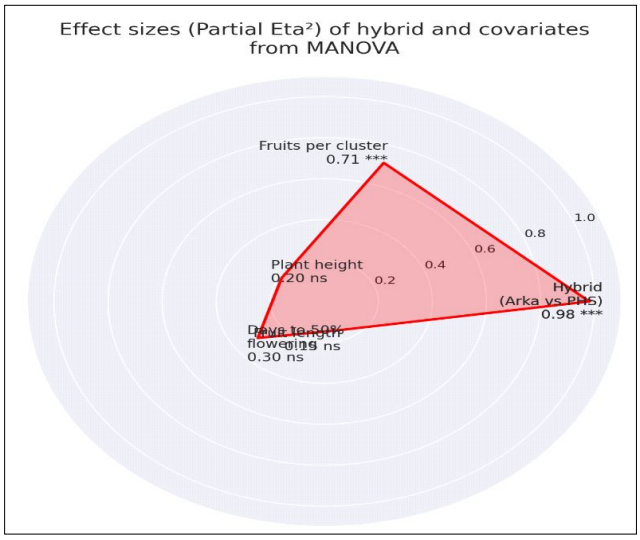

Fig 2: Effect sizes of hybrid and covariates from MANOVA.

variance7-0.95) indicating strong predictive efficiency. Similar findings were recorded by Meena *et al.* (2018) and Rani *et al.* (2020).

Fig 3 illustrates the significance (p-values) of different factors on tomato yield traits using a heatmap. Darker green shades indicate stronger significance (lower p-values), while red shades denote non-significance. The results show that fruits per cluster had the strongest and most consistent effect across fruits per plant, yield per plant and yield per hectare (p<0.001). Plant height significantly influenced fruits per plant, yield per plant and yield per hectare, whereas days to 50% flowering was significant only for average fruit weight. Hybrid differences were significant for fruits per plant and yield per plant, confirming the superior performance of Arka Samrat.

The present findings clearly establish Arka Samrat as a superior hybrid compared to PHS 448, with significantly higher fruit set and per-plant yield. Although average fruit weight and yield per hectare were also higher, these differences did not reach statistical significance. The study highlights the critical role of fruits per cluster and plant height as key determinants of tomato productivity, corroborating earlier reports that fruit set is a primary driver of yield variation in tomato.

Overall, the integration of multivariate and univariate analyses provided a robust underst anding of hybrid performance and trait interrelationships. The results emphasize that Arka Samrat is better suited for commercial cultivation under the studied conditions, while trait-based selection for fruits per cluster and plant height can further guide breeding and evaluation programs.

Disease incidence comparison between Arka Samrat vs PHS 448

The evaluation of disease incidence (Table 4) revealed significant differences between the two tomato hybrids for all three major diseases (Early blight, tomato leaf curl virus (ToLCV) and Bacterial Wilt). Arka Samrat exhibited markedly lower disease levels compared to PHS 448 across 15 replications. For Early Blight, Arka Samrat had a

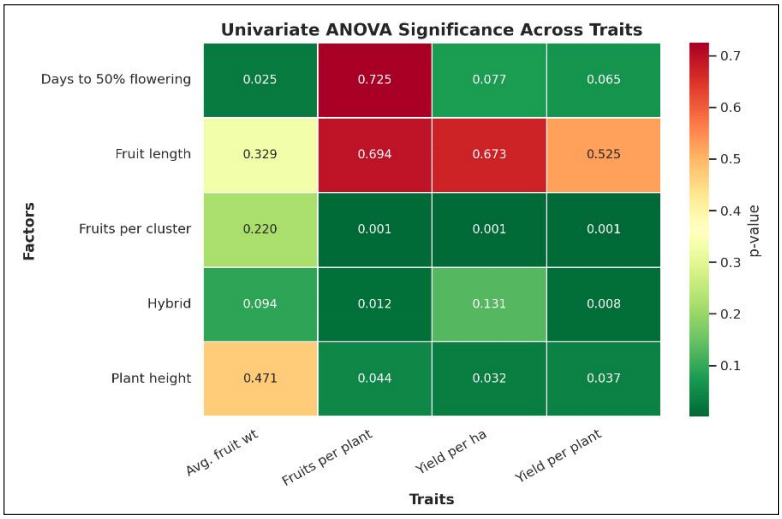

Fig 3: Heatmap of Univariate ANOVA**.**

Table 4: Disease incidence comparison between Arka Samrat vs PHS 448.

Diseases	Mean		SD		t stat	p value	Relative reduction (%)
	Arka Samrat	PHS-448	Arka Samrat	PHS-448			
Early Blight	6.35	36.99	2.24	8.23	-13.91	2.24393E-10	82.839
ToLCV	3.99	10.77	1.78	1.98	-9.86	1.46815E-10	62.985
Bacterial Wilt	2.59	8.87	0.85	1.75	-12.49	5.40858E-11	70.827

Table 5: Cost economics of Arka Samrat and PHS 448 (three years pooled data).

Hybrids	Yield (t/ha)	% increase in yield	Gross cost (Rs./ha)	Gross income (Rs./ha)	Net income (Rs./ha)	BCR
Arka Samrat (Demo)	66.43	65	1,18,885	3,65,390	2,46,505	3.07
PHS 448 (Check)	40.15		1,54,215	2,20,860	66,644	1.43

mean incidence of 6.35% (SD= 2.24), while PHS 448 showed 36.99% (SD= 8.23). The two sample t-test indicated a high significant difference (t = -13.91, p<0.001), with Arka Samrat showing an 82.84% reduction in disease incidence compare to PHS 448. In the case of TLCV, Arka Samrat recorded a mean incidence of 3.99% (SD= 1.78), significantly lower than PHS 448 (10.77%, SD= 1.98; t = -9.86, p<0.001), corresponding to a 62.99% reduction. For Bacterial Wilt, the mean incidence in Arka Samrat was 2.59% (SD= 0.85), compared to 8.87% (SD= 1.75) in PHS 448. The difference was statistically significant (t= -12.49, p<0.001) with a 70.83% reduction in Arka Samrat. These findings are similar with findings of Sadashiva *et al.* (2022), Prasanna and Ravuri (2021).

Overall, these results indicate that Arka Samrat possesses strong resistance to all three diseases relative to PHS 448, highlighting its potential for cultivation in areas prone to these major tomato pathogens.

Economic impact between Arka Samrat vs PHS-448

It observed that, the cost of cultivation for per hectare of Arka Samrat was Rs. 1,18,885/- and recorded average yield of 66.43 t/ha. Farmers sold tomato at average price of Rs. 5.5/kg and obtained gross returns as Rs. 3,65,390/ha and high net returns of Rs. 2,46,505/ha with B:C ratio of 1:3.07. Regarding check hybrid PHS 448, cost of cultivation for per hectare was Rs. 1,54, 215/- and recorded average yield of 40.15 t/ha. Farmers sold tomato at average price of Rs. 5.5/kg and obtained gross returns as Rs. 2,20,860/ha and high net returns of Rs. 66,644/ha with B:C ratio of 1:1.43. Also Arka Samrat was recorded 65% highest yield increases as compared to check PHS 448 were presented in the Table 5.

The potential yield of Arka Samrat under optimal conditions was estimated at 80 t/ha. Under demonstration in farmers field (improved practices), the average actual yield achieved was 66.43 t/ha, while in farmers' practice (check plots), the yield was significantly lower at 40.15 t/ha were presented in Table 5. This corresponds to a 65% increase in yield over the local check, clearly indicating the superiority of the hybrid and the effectiveness of the improved agronomic practices. Similar findings on enhanced yield and profitability of improved tomato hybrids were reported by Bhanu Murthy and Laitha Kameswari (2024); Babu *et al.* (2023) and Shilpa *et al.* (2024).

CONCLUSION

It was concluded that cultivation of Arka Samrat in Kurnool district was found to be highly beneficial owing to its superior performance in growth, yield, yield-attributing characters, and reduced disease incidence. Among the two hybrids evaluated, Arka Samrat consistently outperformed the check hybrid with respect to number of fruits per plant, average fruit weight, total yield and tolerance to major diseases. Based on the results obtained, Arka Samrat is well suited for large-scale cultivation under irrigated dryl and conditions of Kurnool district, characterized by an average annual rainfall of about 650 mm and mean temperature of around 32°C. The hybrid performed satisfactorily during both *kharif* and *rabi* seasons, indicating its adaptability to seasonal variations in the region.

Therefore, cultivation of Arka Samrat can be recommended for commercial production to enhance productivity, profitability and livelihood security of farmers in the irrigated dryl and ecosystems of Kurnool district Andhra Pradesh.

ACKNOWLEDGEMENT

The authors acknowledged the support extended by Sri. P. Balaji, Secretary, SHE and CS, Krishi Vigyan Kendra, Yagantipalle and Dr. Shaik N. Meera, Director, ICAR ATARI-Zone X, Hyderabad.

Author's contribution

M. Adinarayana, Conducted FLD, Collection of Bio metric data and original draft, E. Ravi Goud, Analysis of data and Secondary Review, D. Balaraju, review of the manuscript, G. Dhanalakshmi, Third review of the draft and P Vishnu Mohan Reddy, Data collection of the FLDs.

Funding

ICAR through ICAR-ATARI, Zone-X, Hyderabad.

Research content

Research content is original and has not been published elsewhere.

Ethical approval

Not applicable.

Conflict of interest

All the authors equally contributed and declare that there is no conflict of interest.

REFERENCES

Alsadon, A., Solieman, T.H.I., Wahb-Allah, M.A., Helaly, A.A., Ali, A.A.M., Ibrahim, A.A. and Saad, M.A.O. (2021). Heterosis, potence ratio and correlation of vegetative, yield and quality traits in tomato genotypes and their performance under arid region. *Indian Journal of Agricultural Research*. **55(1):** 33-41. doi: 10.18805/IJARe.A-488.

Babu, N.S., Kumara, N.R., Gouria, V., Raoa, K.S., Kumar, N.K., Babua, P., Sowjanayaa, A. and Naidu, P.R. (2023). Performance of tomato hybrids Arka Abhed and Arka Samrat in Visakhapatnam District of Andhra Pradesh, India. *International Journal of Environment and Climate Change*. **13(8):** 826-836.

Banerjee, M.K. and Kalloo, G. (1987). Sources of inheritance of resistance to leaf curl virus in *Lycopersicon. Theoretical and Applied Genetics.* **73:** 707-710.

Bhanu Murthy, K.C. and Laitha Kameswari, P. (2024). Performance evaluation of tomato hybrids Arka Samrat and Arka Abhedh in Alluri Sitarama Raju District of Andhra Pradesh, India. *Journal of Advances in Biology and Biotechnology.* **27(10):** 1427-1436.

Dhaliwal, M.S. (1986). Heterosis breeding in tomato. Theory and practice. *Seeds and Farms.* **3(12):** 37-39.

Dhillon, N.S. (2019). Assessment of tomato hybrids for yield and quality attributes under protected environment. *International Journal of Current Microbiology and Applied Sciences*. **8(5):** 3334-3342.

Hair, J.F. Jr., Black, W.C., Babin, B.J. and Anderson, R.E. (2019). Multivariate Data Analysis. 8th Edition. Cengage Learning, Hampshire, United Kingdom.

Islam, M.R., Ahmad, S. and Rahman, M. (2012). Heterosis and qualitative attributes in winter tomato (*Solanum lycopersicum* L.) hybrids. *Bangladesh Journal of Agricultural Research*. **37:** 39-48.

Kaddi, G, Tomar, B.S., Singh, B. and Kumar, S. (2014). Effect of growing conditions on seed yield and quality of cucumber (*Cucumis sativus*) hybrid. *Indian Journal of Agricultural Sciences.* **84:** 624-627.

Kumar, D., Kumar, R., Kumar, S., Bhardwaj, M.L., Thakur, M.C., Kumar, R. and Thakur, K.S. (2013). Suitability of tomato (*Solanum lycopersicum* L.) hybrids for mid-hill conditions of Himachal Pradesh. *International Journal of Farm Sciences*. **3(2):** 15-20.

Kumar, S., Pandey, R. and Gupta, S. (2018). Morphological and yield variability in tomato hybrids under open field conditions. *Indian Journal of Horticulture*. **75(3):** 462-468.

Meena, O.P., Bahadur, V. and Singh, D. (2018). Correlation and path coefficient analysis for yield and yield components in tomato (*Solanum lycopersicum* L.). *International Journal of Current Microbiology and Applied Sciences*. **7(2):** 1449-1457.

Mew, T.W. and Ho, W.C. (1976). Varietal resistance to bacterial wilt in tomato. *Plant Disease Reporter*. **60:** 264-268.

Mishra, D., Ashis Kumar, M., Mukhi, S.K. and Singh, DV. (2019). Assessing the performance and adoption rate of tomato hybrid Arka Rakshak having multiple disease resistance in Jagatsinghpur district of Odisha, India. *International Journal of Current Microbiology and Applied Sciences*. **8(9):** 2458-2464.

National Horticulture Board. (2020). Indian Horticulture Database, Department of Agriculture and cooperation, Government of India. www.nhb.gov.in.

Nayana, K.R., Srinivasa, V., Devaraju and Shrilatha, K.A. (2024). Enhanced growth and yield in semi-indeterminate tomato (*Solanum lycopersicum*): A heterosis study under protected condition. *The Indian Journal of Agricultural Sciences*. **94(10):** 1148-1152.

Nkansah, G.O., Amoatey, C., Zogli, M.K., Owusu-Nketia, S., Ofori, P.A. and Opoku-Agyemang, F. (2021). Influence of topping and spacing on growth, yield and fruit quality of tomato (*Solanum lycopersicum* L.) under greenhouse condition. *Frontiers in Sustainable Food System*. **5:** 659047.

Panse, V.G. and Sukhatme, P.V. (1967). Statistical Methods for Agricultural Workers. 2nd Edn., Indian Council of Agricultural Research, New Delhi. P 381.

Prasanna Lakshmi and Ravuri. (2021). Assessment of late blight resistant tomato hybrid Arka Abhed. *Biological Forum-An International Journal.* **13(3):** 613-616.

Rani, S., Kumar, R., Singh, M. and Singh, A.K. (2020). Genetic variability, heritability and association analysis for yield and yield contributing traits in tomato (*Solanum lycopersicum* L.). *Journal of Pharmacognosy and Phytochemistry.* **9(5):** 2163-2167.

Reddy, B.P., Narayanamma, V.L. and Sudhakar, P. (2016). Genetic variability and association studies in tomato (*Solanum lycopersicum* L.) for yield and quality traits. *The Bioscan.* **11(2):** 1143-1146.

Remzeena, A., Anitha, P., Pradeepkumar, T., Aswini, A., Beena, V.I. and Anoop, E.V. (2023). Evaluation of tomato hybrids for growth, yield and quality attributes under the climatic conditions of Kerala. *Biological Forum- An International Journal.* **15(11):** 370-375.

Sadashiva, A.T., Oberoi, H.S., Singh, T.H., Prasanna, H.C., Madhavi Reddy, K., Krishna Reddy, M., Ravishankar, K.V. and Nayana, R.S. (2022). Breeding tomatoes suitable for processing with triple disease resistance to tomato leaf curl disease, bacterial wilt and early blight. *Journal of Horticultural Sciences.* **17(2):** 278-292.

Saravanan, K.R., Vishnupriya, V., Prakash, M. and Anandan, R. (2019). Variability, heritability and genetic advance in tomato genotypes. *Indian Journal of Agricultural Research.* **53(1):** 92-95. doi: 10.18805/IJARe.A-5030.

Sharma, A., Pandey, S.K. and Nair, R. (2021). Correlation and path co-efficient analysis for yield and its contributing traits in tomato (*Solanum lycopersicum* L.). *The Pharma Innovation Journal.* **10(3):** 616-622.

Shilpa, Bijalwan, P. and Shukla, Y.R. (2024). Influence of different training levels on fruit quality and yield of tomato (*Solanum lycopersicum* L.) under the mid-hill conditions of Himachal Pradesh. *Indian Journal of Agricultural Research.* **58(6):** 1266-1270. doi: 10.18805/IJARe.A-5838.

Singh, R.K., Kumar, P. and Rai, M. (2017). Correlation and path coefficient analysis in tomato hybrids. *Vegetable Science.* **44(1):** 65-71.

Tabachnick, B.G. and Fidell, L.S. (2013). Using Multivariate Statistics (6th ed.). Pearson.