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Assessment of recommended tomato varieties by IIHR through on farm trials (OFT'S) for Vidarbha region of Maharashtra

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Abstract

This paper analyses on-farm trial data comparing three tomato entries (Vinayak (T_1), Arka Rakshak (T_2) and Arka Samrat (T_3)) and documents respondent profiles, knowledge and adoption levels, yield, technology/extension gaps and economics. Descriptive statistics (percentages, means, standard deviations and coefficient of variation where informative) are used to explain each table. The study finds higher mean yield and benefit:cost (B:C) for Arka Rakshak (T_2) and a substantial technology gap between research potential and on-farm yield. Policy implications for extension and technology dissemination are discussed with recent references.

Keywords: Tomato varieties, on-farm trials, IIHR varieties

Introduction

Tomato (*Solanum lycopersicum*) is a high-value vegetable crop in India; hybrid development (e.g., Arka series) has focused on disease resistance and higher yield. On-farm comparisons and frontline demonstrations are important to quantify yield gains, technology gaps and economic returns under farmers' conditions and inform extension priorities. Recent literature emphasizes measuring technology gap, extension gap and economic indicators (yield increase percentages, B:C ratios) to evaluate on-farm impact.

Materials and Methods

Key variables include respondent socio-demographics, knowledge/adoption scores, yield (q/ha), extension & technology gap metrics and economic parameters (gross cost, gross return, net return, B:C ratio). The Socio-demographic Profile included age, education, farm size, income, socio-economic status, innovativeness, scientific orientation, economic motivation, and risk preference. The Socio-economic Status was measured with the help of SES Scale developed by Thakare and Ingle (2007) [18].

Regular monitoring was conducting on the exhibited trials and all relevant data pertaining to the required qualities were gathered. The parameters i.e. technology gap, extension gap and technology index were calculated by using formula suggested by Saui *et al.*, (2000).

$$\text{Extension gap (q ha}^{-1}\text{)} = \text{Demonstration yield - Farmers yield}$$

$$\text{Technology gap (q ha}^{-1}\text{)} = \text{Potential yield - Demonstration yield}$$

$$\text{Technology Index (\%)} = \frac{\text{Potential yield - Demonstration yield}}{\text{Demonstration yield - Farmers yield}} \times 100$$

Results and Discussion

Socio-economic and Personal Profile of the Respondents

The socio-economic and personal characteristics of the respondents are presented in Table 1. These characteristics are essential for understanding their resource base, access to information, and the likely responsiveness to extension interventions.

The data revealed that 48.72 per cent of respondents were in the 6-10 years category, followed by 41.03 per cent in the up-to-5 years category, and only 10.26 per cent in the 11 years and above group. The overall mean age was 37.97 years with a standard deviation of 8.81. This indicates that the majority of the respondents were in their middle age, implying active involvement and openness toward new agricultural technologies. Younger and middle-aged farmers are often more energetic, adaptive, and experimental in adopting improved practices compared to older counterparts (Singh *et al.*, 2014) [16]. A similar age pattern among progressive farmers was reported by Patel *et al.* (2020) and Thorat *et al.* (2022) [19], who found that middle-aged farmers were dominant participants in extension programmes.

Education plays a vital role in technology adoption and comprehension of technical information. In the present study, none of the respondents were illiterate. About 17.95 per cent had education up to middle school, 15.38 per cent up to high school, 28.21 per cent up to junior college, and 38.46 per cent were graduates or above. The mean education level was 11.95 years of schooling with an SD of 2.96. This indicates a highly educated group of farmers compared with the national rural average. Education enhances farmers' capacity to interpret extension advice and manage scientific farming systems efficiently (Meena *et al*., 2018; Singh *et al*., 2019) [3, 12]. The higher proportion of graduates in the present sample suggests a strong potential for rapid technology diffusion through peer learning.

The results show that 53.85 per cent of respondents were marginal farmers, 30.77 per cent were small, and 15.38 per cent were semi-medium farmers, with no medium or large holdings. The average landholding was 1.27 ha (SD = 0.60). The predominance of marginal and small holdings aligns with the national scenario, where over 85 per cent of operational holdings are below 2 ha (Government of India, 2019) [1]. This indicates that the sample reflects the structural characteristics of Indian agriculture. Similar findings were reported by Patel and Meena and Singh (2020) [4]. Smaller holdings imply constraints in capital and resource availability but also an opportunity for KVK interventions to promote high-value crops, integrated farming systems, and low-cost technologies suited for limited land.

The majority of respondents (53.85%) earned between ₹ 1,00,001 and ₹ 2,00,000 annually, followed by 33.33 per cent in the ₹ 2-3 lakh category. Only 7.69 per cent had incomes above ₹ 3 lakh. The mean income was ₹ 1.80 lakh per annum. These figures are comparable to NABARD's All India Rural Financial Inclusion Survey (2022) [5], which places the median annual income of smallholders around ₹ 1.7 lakh. Lower annual incomes among marginal and small farmers underline the need for livelihood diversification and value-addition interventions through KVKs.

The socio-economic status (SES) index revealed that 33.33 per cent of respondents belonged to the "high" category and 38.46 per cent to the "very high" category, while only 10.26 per cent were "low". The mean SES score was 7.23 (SD = 1.76). This indicates that nearly three-fourths of respondents maintained a moderate-to-high standard of living. High SES, despite small landholdings, suggests diversified income sources, educational attainment, and asset ownership. Similar findings were observed by Meena and Singh (2020) [4], who found that education and non-farm income substantially improve rural SES indices.

Extension contact was found to be moderate to high among most respondents: 58.97 per cent reported moderate and 35.90 per cent high contact levels (mean = 10.02, SD = 1.95). None fell in the low-contact category. This demonstrates a strong linkage with extension systems, particularly with KVKs. High extension contact is a key determinant of improved knowledge, skill, and adoption of innovations (Sundaramari and Ramasubramanian, 2017; Singh *et al*., 2020) [17,].

Regarding visits to KVKs, 41.03 per cent each reported visiting once or twice per season, and 10.26 per cent more than twice per season, whereas only 7.69 per cent had never visited. The mean frequency score was 1.54 (SD = 0.79). Frequent visitation indicates strong engagement with the KVK system and validates the success of frontline demonstrations and on-campus training as effective extension tools. Similar patterns were noted by Meena *et al*. (2018) [3] and Thorat *et al*. (2022) [19], who observed that repeated exposure to KVK activities improved farmers' knowledge and skill retention.

Social participation analysis revealed that 28.21 per cent of respondents had moderate participation, while 51.28 per cent exhibited high or very high participation levels. The mean social participation score was 2.56 (SD = 1.10). High social participation reflects membership in farmer organizations, self-help groups (SHGs), and cooperatives. Such participation builds social capital and fosters collective learning and market access (Narayanan *et al*., 2021) [6].

The composite picture of the respondents indicates a younger, educated, smallholder group with strong extension linkage and active social engagement. Such a profile is highly favorable for technology dissemination, as education and extension contact jointly enhance the adoption process (Sundaramari and Ramasubramanian, 2017) [17]. However, modest annual income and limited landholding continue to constrain investment capacity, emphasizing the need for low-cost, high-return technologies and collective approaches through FPOs or cooperatives.

Psychological and Behavioural Characteristics of the Respondents

The psychological and behavioural traits of farmers influence their decision-making, innovativeness, and responsiveness to new agricultural technologies. The present study assessed four key behavioural attributes; economic motivation, scientific orientation, risk preference, and innovativeness which play a crucial role in determining technology adoption and participation in KVK programmes (Table 2).

The results indicate that 33.33 per cent of the respondents had a high level of economic motivation, while 38.46 per cent exhibited a very high level. About 17.95 per cent had moderate, and only 10.26 per cent had low motivation levels. The overall mean score was 18.06 with an SD of 4.41. These findings imply that the majority of farmers were economically driven, striving to increase their farm income and productivity. Economic motivation is a key driver for adopting improved technologies, as financially oriented farmers actively seek profitable innovations and respond positively to demonstrations and training (Rogers, 2003) [9]. Similar observations were reported by Patel and Meena and Singh (2020) [4] and Meena *et al*. (2018) [3], who found that farmers with high economic motivation are more likely to participate in extension activities and adopt scientific practices. This strong motivation among respondents could be attributed to the success and visible benefits of KVK demonstrations, which have shown substantial yield and profit advantages.

Scientific orientation reflects the extent to which an individual believes in and applies scientific methods in farming. In this study, 38.46 per cent of respondents had a high level of scientific orientation, and 33.33 per cent were in the very high category, together forming over 71 per cent of the sample. Only 7.69 per cent had low orientation. The mean score was 17.63 (SD = 5.12). This indicates that respondents exhibited a strong inclination toward scientific farming, which is an encouraging indicator for the dissemination of new technologies. Farmers with higher scientific orientation tend to adopt innovations early and rely more on verified information sources (Sundaramari & Ramasubramanian, 2017) [17]. The observed results agree with Thorat *et al*. (2022) [19] and Singh *et al*. (2019) [14], who reported that farmers associated with KVKs demonstrated higher scientific orientation and knowledge gain compared to non-participants.

Risk preference represents a farmer's willingness to accept uncertainty in the hope of gaining higher returns. The study found that 46.15 per cent of respondents had a very high level of risk preference, 30.77 per cent were high, and only 7.69 per cent were low. The mean score was 19.54 with an SD of 6.11, reflecting a generally high-risk-taking attitude among the respondents. This suggests that most farmers were entrepreneurial and confident in experimenting with new practices, possibly due to the support and assurance provided by KVK demonstrations and extension staff. High risk preference among farmers indicates readiness to adopt new technologies and diversify into innovative enterprises. These results corroborate the findings of Meena and Singh (2020) [4] who highlighted that exposure to extension programmes significantly enhances farmers' confidence and willingness to take calculated risks.

Innovativeness measures the degree to which an individual is open to adopting new ideas and practices. The data show that 43.59 per cent of respondents exhibited very high innovativeness, followed by 28.21 per cent with high and 17.95 per cent with moderate levels. Only 10.26 per cent had low innovativeness, and none were in the very low category. The mean score was 18.81 (SD = 5.93). This finding implies that a majority of the farmers were progressive and receptive to new technologies. Such farmers often act as opinion leaders within their communities, facilitating peer learning and diffusion of innovations (Rogers, 2003) [9]. High innovativeness levels may result from continuous exposure to KVK training, demonstrations, and advisory services, which build confidence and curiosity to test new practices. Comparable results were reported by Patel *et al*. (2020) and Thorat *et al*. (2022) [19], who observed that KVK-trained farmers maintained higher innovativeness and adoption indices than their untrained counterparts.

Overall, the psychological profile of respondents indicates a progressive, motivated, and scientifically oriented group with high risk-taking ability and innovativeness. Such behavioural attributes form a strong foundation for agricultural modernization and effective utilization of extension services. These traits are consistent with the innovation-decision process proposed by Rogers (2003) [9], wherein economic motivation, scientific orientation, and risk-taking collectively determine the rate of adoption. High motivation and innovativeness among KVK-associated farmers suggest that the institutional environment is successfully nurturing a proactive mindset towards scientific farming. However, continued exposure, need-based training, and participatory demonstration are essential to sustain these positive traits and extend similar behavioural transformation to other farmer groups.

Knowledge of Tomato Cultivation Practices

The knowledge and adoption status of respondents regarding tomato cultivation practices is presented in Table 3. The assessment covered six major components: land preparation, varieties/planting material, sowing/transplanting, irrigation, nutrient management, and plant protection. The percentages indicate the proportion of respondents aware of or adopting each recommended practice.

Respondents showed considerable awareness of fundamental land preparation practices. About 76.92% were aware of proper ploughing techniques, 58.97% understood the importance of avoiding waterlogging, 56.41% recognized suitable soil types, 51.28% prepared beds appropriately, and 48.72% applied FYM as recommended. Proper land preparation is critical for aeration, root development, and nutrient uptake, particularly for tomatoes, which are sensitive to waterlogging and poor soil fertility (Singh *et al*., 2018) [13]. The relatively high awareness of ploughing and water management reflects routine extension guidance, whereas lower awareness of FYM application suggests a need for further emphasis on organic matter management.

Knowledge of crop variety selection and seedling management was moderate to high. Transplanting was the most widely practiced activity (97.44%), followed by seedling preparation (82.05%), seed treatment (61.54%), traits of good varieties (53.85%), and choice of crop variety (46.15%). High transplanting adoption indicates farmers understand its importance for establishing uniform stands, improving growth, and reducing early crop losses. The moderate knowledge of variety traits reflects the need for continued training on selecting high-yielding, disease-resistant cultivars suitable for local conditions.

Respondents displayed variable adoption for timing and spacing practices. Depth of transplanting (89.74%) and precautions while transplanting (84.62%) were highly adopted, whereas timing of transplanting (48.72%), spacing for determinate varieties (51.28%), and spacing for indeterminate varieties (64.10%) were moderately followed. Proper transplanting depth and spacing are essential for optimal canopy development, air circulation, and disease reduction. Previous studies highlight that incorrect spacing or delayed transplanting can reduce yields and increase pest/disease incidence (Meena *et al*., 2018) [3]. The high adoption of transplanting precautions demonstrates responsiveness to KVK training, whereas spacing adjustments require further reinforcement.

Irrigation management is crucial for tomato growth and yield. Respondents were aware of irrigation schedules (76.92%), irrigation during flowering/fruiting (87.18%), maintenance of drip lines (82.05%), losses due to over-irrigation/waterlogging (66.67%), and criteria for deciding irrigation timing (74.36%). These findings indicate that farmers are relatively knowledgeable about critical irrigation periods and micro-irrigation maintenance, which aligns with modern recommendations for water use efficiency in tomato cultivation (Singh *et al*., 2019) [15]. However, gaps remain in preventing losses from excessive irrigation, suggesting the need for hands-on demonstration and drip scheduling training.

Knowledge of nutrient management practices was relatively high, with 94.87% following fertigation recommendations, 87.18% observing fertilizer precautions, 71.79% applying micronutrients timely, 69.23% applying nitrogen appropriately, and 53.85% aware of the recommended NPK dose. The high adoption of fertigation reflects the growing use of modern drip-based nutrient delivery systems in tomato cultivation. Timely micronutrient and nitrogen management ensures fruit quality and yield. However, the moderate knowledge of recommended NPK doses suggests that farmers need further support in calculating fertilizer requirements based on soil tests and crop demand (Meena *et al*., 2018) [3].

Respondents demonstrated good awareness of pest and disease management. Major pests were recognized by 71.79%, major diseases by 79.49%, preventive fungicide sprays by 69.23%, cultural pest/disease management practices by 84.62%, and time of harvesting by 79.49%. This indicates that farmers are proactive in integrated pest management (IPM) practices, consistent with findings from KVK training programs (Singh *et al*., 2018) [13]. Cultural practices for disease prevention and timely harvesting were well adopted, reflecting responsiveness to extension recommendations. However, preventive fungicide usage could be improved to reduce disease incidence and improve fruit quality.

Thus, Nearly 44% of respondents are in the high knowledge category, and the majority (about 90%) are at least moderate. The SD (5.82) shows some heterogeneity. Extension messages can leverage the existing knowledge base (peer demonstration) but should target the 10% low-knowledge farmers and areas with specific gaps (FYM etc.).

The findings reveal that farmers possess moderate to high knowledge and adoption of recommended tomato cultivation practices. Highest adoption was observed in transplanting, fertigation, transplanting precautions, and irrigation during flowering/fruiting, while moderate adoption was noted in fertilizer dose calculation, variety selection, and pest preventive sprays. This pattern suggests that hands-on practices with visible results (transplanting, fertigation) are more likely to be adopted than abstract or technical recommendations (soil nutrient dose, variety traits). Similar adoption trends have been reported by Meena *et al*. (2018) [3], where KVK interventions increased practical adoption while knowledge-intensive practices required further reinforcement.

Although knowledge scores were relatively high for many recommended practices (especially transplanting and fertigation), adoption of some soil fertility practices (FYM, recommended NPK dose) was lower. Bridging this knowledge-practice gap could improve nutrient status and further reduce the technology gap. Recommendations from NHB/ICAR on NPK and FYM can guide extension messages (e.g., recommended N ~ 90-120 kg/ha depending on guidelines and hybrid requirements

Adoption of Tomato Cultivation Practices

The knowledge and adoption of recommended tomato cultivation practices by respondents are summarized in Table 4. The assessment covered six major components: land preparation, varieties/planting material, sowing/transplanting, irrigation, nutrient management, and plant protection. The percentages indicate the proportion of respondents aware of or adopting each practice.

Respondents demonstrated moderate adoption of land preparation practices. Ploughing was practiced by 69.23% of respondents, avoiding waterlogging by 51.28%, selecting suitable soil type by 53.85%, bed preparation by 46.15%, and FYM application by 43.59%. Although the majority understood ploughing and water management, organic matter management (FYM application) was relatively low. Proper land preparation, including ploughing, bed preparation, and FYM application, is essential for aeration, nutrient availability, and root development, particularly for tomato crops, which are highly sensitive to soil structure and fertility (Singh *et al*., 2018) [13]. These results indicate that farmers prioritize visible and routine practices but may need additional guidance on organic amendments.

High adoption was recorded for seed treatment (92.31%) and transplanting (74.36%), followed by seedling preparation (58.97%), traits of good varieties (48.72%), and crop variety selection (43.59%). The high adoption of seed treatment reflects awareness of disease prevention and seedling protection measures. Lower adoption in variety selection indicates that farmers may not fully differentiate between high-yielding or disease-resistant cultivars. Strengthening farmer awareness of variety traits is essential for maximizing productivity.

Depth of transplanting (79.49%) and transplanting precautions (74.36%) were widely adopted, while timing of transplanting (43.59%) and spacing for determinate (48.72%) and indeterminate varieties (56.41%) showed moderate adoption. These results suggest that farmers prioritize practical transplanting procedures that directly impact plant establishment, but technical recommendations such as precise spacing and optimal timing require reinforcement through demonstrations and hands-on training (Meena *et al*., 2018) [3].

Adoption of irrigation practices was relatively high. Farmers followed irrigation during flowering and fruiting (82.05%), regular irrigation schedules (71.79%), drip line maintenance (74.36%), criteria for irrigation timing (66.67%), and were aware of losses due to over-irrigation (61.54%). Effective water management is critical for tomato yield and quality. The results indicate a positive response to KVK training on irrigation practices, particularly for critical crop growth stages. However, further training may be required to reduce over-irrigation losses, which can cause nutrient leaching and disease incidence (Singh *et al*., 2019) [12].

High adoption was observed for fertigation (89.74%) and fertilizer precautions (79.49%), followed by micronutrient application timing (61.54%), nitrogen application timing (58.97%), and awareness of recommended NPK doses (48.72%). This indicates that farmers actively adopt modern fertigation methods but need additional guidance on precise nutrient dosing to optimize input use efficiency and avoid nutrient imbalances (Meena *et al*., 2018) [3].

Farmers showed good knowledge of pest and disease management. Awareness of major diseases (74.36%), cultural practices (76.92%), time of harvesting (71.79%), major insects (66.67%), and preventive fungicide sprays (66.67%) was moderate to high. These results demonstrate adoption of integrated pest and disease management practices, indicating that KVK interventions effectively build farmers' capacity to prevent and manage crop losses. Nonetheless, adoption of preventive fungicide sprays could be improved for better disease control and fruit quality (Singh *et al*., 2018) [13].

Thus, most farmers fall into the moderate adoption category. The small percentage (20.5%) in high adoption suggests room for scaling best practices; extension should focus on converting the moderate adopters to high adopters through focused demonstrations and input support. The results reveal moderate to high adoption of tomato cultivation practices. Practices with visible outcomes, such as seed treatment, fertigation, transplanting precautions, and irrigation during flowering/fruiting, were more widely adopted than technical knowledge-based practices like nutrient dosing, variety selection, and spacing for different varieties. This pattern highlights the importance of practical demonstrations for adoption, as observed in other KVK-led studies (Meena *et al*., 2018) [3]. Extension programs should continue hands-on field demonstrations, with special emphasis on knowledge-intensive practices such as soil nutrient management, spacing, and preventive plant protection measures, to further improve productivity and adoption rates.

Technological and Extension Gap in Tomato Cultivation

The technological and extension gaps in tomato cultivation are presented in Table 8. Average Extension Gap was 70.00 q/ha with a standard deviation of 29.55 q/ha. This indicates a significant gap between the recommended technology and the level of adoption by farmers, despite the existing extension services. Average Yield Increase over Farmers' Practice was 15.08% (SD = 4.68), reflecting the positive impact of improved practices promoted by KVKs. This moderate yield increase indicates that while farmers adopt some recommendations, complete adoption is still limited, which constrains yield maximization. Average Technology Gap was 279.17 q/ha with SD 106.73, suggesting a substantial difference between the potential yield achievable with recommended practices and the yield obtained under current farmer practices. Average Technology Index was 34.86% (SD = 13.28), indicating that there is a significant scope for improving productivity by adopting scientific and improved tomato cultivation techniques (Samui *et al*., 2000) [11]. A lower technology index reflects higher efficiency in technology adoption; here, a 34.86% index highlights a moderate adoption level.

While extension demonstrations improved farmer yields, a large technology gap persists — reasons often include localized constraints (soil fertility, pest pressure, input access, management intensity) and indicate the need for adaptive research and stronger extension support. This pattern is consistent with other yield-gap studies in tomato. These results suggest that extension efforts need to be intensified to minimize the technology and extension gap. Farmers require additional training, demonstrations, and follow-up visits to bridge this gap, particularly for nutrient management, spacing, and pest/disease control (Meena *et al*., 2018) [3].

Economics of Tomato Cultivation

The economics of tomato cultivation for three varieties — Vinayak (T_1), Arka Rakshak (T_2), and Arka Samrat (T_3) are presented in Table 9. The gross cost of cultivation ranged from ₹81,526.67 to ₹83,123.33 per hectare, with T_1 having slightly higher costs due to management practices. Standard deviation in cost was relatively low, indicating uniformity in cultivation practices across treatments. Arka Rakshak (T_2) recorded the highest gross return (₹2,89,853.33/ha) followed by Arka Samrat (T_3: ₹2,75,438.33/ha) and Vinayak (T_1: ₹2,51,966.67/ha). Standard deviation was highest for T_2, suggesting some variability in market prices or yields among farmers. The net return was highest in Arka Rakshak (T_2: ₹2,08,326.67/ha), followed by Arka Samrat (T_3: ₹1,93,911.67/ha) and Vinayak (T_1: ₹1,68,843.33/ha). This indicates that adoption of improved varieties can significantly increase profitability. The B:C ratio was highest for Arka Rakshak (3.54), followed by Arka Samrat (3.37) and Vinayak (3.03). A B:C ratio above 3.0 suggests highly remunerative cultivation. The SD of B:C ratios was lowest for Vinayak (0.03) and higher for T_2 and T_3, indicating variation in returns among farmers.

The economic analysis demonstrates that Arka Rakshak (T_2) is the most profitable variety under the given agro-climatic conditions. Improved varieties, coupled with recommended practices, enhance both yield and income. High B:C ratios indicate that tomato cultivation is economically viable and adoption of recommended technology can significantly improve farmer livelihoods (Patel & Meena, 2020).

Arka Rakshak (T_2) gives the highest gross return (Rs. 289,853/ha) and highest net return (Rs. 208,326.67/ha) with the best B:C ratio of 3.54, indicating highest economic attractiveness among the three varieties under these on-farm conditions. This aligns with published on-farm reports where Arka Rakshak often gives superior returns due to disease resistance and high marketable yield. Costs are comparable across treatments; variation in returns drives profitability differences. The relatively low CV for gross/net returns shows returns are reasonably stable across demonstration plots, although Arka Rakshak shows somewhat higher variability (reflecting yield variability). The B:C ratios here (≈3.0-3.5) suggest very profitable production under the demonstrated management — higher than some district-level averages reported in other studies, but comparable to successful KVK/FLD demonstrations elsewhere; economic results depend heavily on price realization, disease incidence, and management intensity.

Arka Rakshak (T_2) shows the highest mean yield and highest economic returns. This is consistent with reports that Arka Rakshak, a triple disease-resistant F1 hybrid developed by IIHR performs well in farmer and protected environments, especially where ToLCV, bacterial wilt and early blight are constraints. Technology and extension gaps: The extension gap (~70 q/ha) and sizable technology gap (~279 q/ha) indicate that while demonstrations improve farmer yields, a considerable yield potential remains unrealized. The high B:C ratios indicate tomato cultivation under these demonstrated practices is profitable. However, economic returns can be volatile due to price fluctuations, so risk mitigation (market linkages, contract farming) and diversification are prudent.

Descriptive Statistics

Arka Rakshak (T_2) recorded the highest mean yield (≈ 526 q ha⁻¹), followed by Arka Samrat (T_3) (≈ 491 q ha⁻¹) and Vinayak (T_1) (≈ 451 q ha⁻¹). There is a statistically significant difference among the mean yields of the three tomato varieties. Arka Rakshak (T_2) yielded significantly higher than Vinayak (T_1). Differences between T_2 vs T_3 and T_3 vs T_1 were not statistically significant at the 5% level. Hence, Arka Rakshak is statistically superior overall. Arka Rakshak (T_2) recorded the highest mean yield of 526.41 q ha⁻¹, which was about 16.8% greater than Vinayak (T_1) and 7.1% greater than Arka Samrat (T_3). The coefficient of variation (≈ 20%) across treatments indicates moderate yield variability, typical of on-farm conditions influenced by soil and management heterogeneity.

ANOVA results ($F = 5.72$, $p = 0.0043$) revealed a significant varietal effect on tomato yield. Tukey's HSD indicated that Arka Rakshak (T_2) produced significantly higher yields than Vinayak (T_1), while the difference between Arka Rakshak and Arka Samrat (T_3) was not significant. The mean yield advantage of T_2 over T_1 was about 75 q ha⁻¹ (≈ 16.8%). Variability (CV ≈ 20%) reflects expected heterogeneity under on-farm conditions.

These findings substantiate earlier reports of Arka Rakshak's superior performance and disease resistance (IIHR 2023; NHB 2024) [2, 7]. They confirm that, under Vidarbha conditions, Arka Rakshak provides a statistically and economically superior choice for tomato growers.

These results demonstrate that Arka Rakshak (T_2) is statistically superior in yield performance compared with the farmers' practice variety Vinayak (T_1). The improvement may be attributed to Arka Rakshak's triple disease resistance—against Tomato Leaf Curl Virus (ToLCV), Bacterial Wilt (*Ralstonia solanacearum*), and Early Blight (*Alternaria solani*)—and its vigorous hybrid growth habit (IIHR 2023) [2]. Similar superiority of Arka Rakshak over local hybrids has been reported in on-farm trials in Telangana and Karnataka (Rani *et al*., 2024; Sahu *et al*., 2023) [8, 10].

Table 1: Personal, situational, socio-economic and communication Profile of the respondents

Sr	Profile	Number	Per Cent	Mean	SD
A	**Age**				
1	Up to 5 Years	16	41.03	37.97	8.81
2	6 to 10 years	19	48.72		
3	11 Years and above	04	10.26		
B	**Education**				
1	Illiterate	00	0.00	11.95	2.96
2	Primary	00	0.00		
3	Middle School	07	17.95		
4	High School	06	15.38		
5	Junior College	11	28.21		
6	Graduate and above	15	38.46		
C	**Land Holding**				
1	Marginal	21	53.85	1.27	0.60
2	Small	12	30.77		
3	Semi-medium	06	15.38		
4	Medium	00	0.00		
5	Large	00	0.00		
D	**Annual Income**				
1	Upto 100000	02	5.13	180000	0.74
2	100001 to 200000	21	53.85		
3	200001 to 300000	13	33.33		
4	300001 to 400000	02	5.13		
5	400001 to 500000	01	2.56		
E	**Socio-economic status**				
1	Very low	00	0.00	7.23	1.76
2	Low	04	10.26		
3	Moderate	07	17.95		
4	High	13	33.33		
5	Very High	15	38.46		
F	**Extension Contact**				
1	Low	00	0.00	10.02	1.95
2	Moderate	23	58.97		
3	High	14	35.90		
G	**Frequency of visit to KVK**				
1	Never in the season	03	7.69	1.54	0.79
2	Once a season	16	41.03		
3	Twice a season	16	41.03		
4	More than twice	04	10.26		
H	**Social Participation**				
1	Low	08	20.51	2.56	1.10
2	Moderate	11	28.21		
3	High	10	25.64		
4	Very High	10	25.64		

Table 2: Psychological Profile of the respondents

Sr	Profile	Number	Per Cent	Mean	SD
A	**Economic motivation**				
1	Very low	00	0.00	18.06	4.41
2	Low	04	10.26		
3	Moderate	07	17.95		
4	High	13	33.33		
5	Very High	15	38.46		
B	**Scientific Orientation**				
1	Very low	00	0.00	17.63	5.12
2	Low	03	7.69		
3	Moderate	08	20.51		
4	High	15	38.46		
5	Very High	13	33.33		
C	**Risk Preference**				
1	Very low	00	0.00	19.54	6.11
2	Low	03	7.69		

3	Moderate	06	15.38		
4	High	12	30.77		
5	Very High	18	46.15		
D	**Innovativeness**				
1	Very low	00	0.00	18.81	5.93
2	Low	04	10.26		
3	Moderate	07	17.95		
4	High	11	28.21		
5	Very High	17	43.59		

Table 3: Knowledge Profile of the respondents

Sr	Item	Number	Per cent
A	**Land preparation / site selection / soil**		
1	Type of Soil	22	56.41
2	Ploughing	30	76.92
3	FYM Application	19	48.72
4	Bed Preparation	20	51.28
5	Avoiding water logging	23	58.97
B	**Varieties / planting material**		
6	Crop Variety	18	46.15
7	Traits of good varieties	21	53.85
8	Seed Treatment	24	61.54
9	Seedling preparation	32	82.05
10	Transplanting	38	97.44
C	**Sowing / transplanting time & spacing**		
11	Time of transplanting	19	48.72
12	Spacing adopt for a determinate tomato variety in open field conditions?	20	51.28
13	Spacing adopt for indeterminate tomato variety in open field conditions?	25	64.10
14	Depth of transplanting tomato	35	89.74
15	Precautions while transplanting	33	84.62
D	**Irrigation schedule / water management**		
16	Regular Irrigation schedule	30	76.92
17	Irrigation schedule during flowering and fruiting	34	87.18
18	Losses due to over irrigation or waterlogging	26	66.67
19	Maintenance of drip irrigation lines	32	82.05
20	Criterion to decide irrigation timing	29	74.36
E	**Nutrient management / fertilization**		
21	What is the recommended dose of N, P, K	21	53.85
22	Timing the application of nitrogen fertilizer in tomato	27	69.23
23	Time of aaplication of micronutrients	28	71.79
24	Fertigation	37	94.87
25	Precautions when applying fertilizer	34	87.18
F	**Plant protection / pests & diseases / other practices**		
26	Major insect	28	71.79
27	Major disease	31	79.49
28	Preventive fungicide sprays	27	69.23
29	Cultural practice practices for Pest and Disease Management	33	84.62
30	Time of harvesting	31	79.49

Table 4: Distribution of respondents according to Knowledge levels

Sr	Knowledge	Number	Per Cent	Mean	Standard Deviation
1	Low	04	10.26	18.92	5.82
2	Moderate	18	46.15		
3	High	17	43.59		

Table 5: Adoption Profile of the respondents

Sr	Item	Number	Per cent
A	**Land preparation / site selection / soil**		
1	Type of Soil	21	53.85
2	Ploughing	27	69.23
3	FYM Application	17	43.59
4	Bed Preparation	18	46.15
5	Avoiding water logging	20	51.28
B	**Varieties / planting material**		

6	Crop Variety	17	43.59
7	Traits of good varieties	19	48.72
8	Seed Treatment	36	92.31
9	Seedling preparation	23	58.97
10	Transplanting	29	74.36
C	**Sowing / transplanting time & spacing**		
11	Time of transplanting	17	43.59
12	Spacing adopt for a determinate tomato variety in open field conditions?	19	48.72
13	Spacing adopt for indeterminate tomato variety in open field conditions?	22	56.41
14	Depth of transplanting tomato	31	79.49
15	Precautions while transplanting	29	74.36
D	**Irrigation schedule / water management**		
16	Regular Irrigation schedule	28	71.79
17	Irrigation schedule during flowering and fruiting	32	82.05
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25	Precautions when applying fertilizer	31	79.49
F	**Plant protection / pests & diseases / other practices**		
26	Major insect	26	66.67
27	Major disease	29	74.36
28	Preventive fungicide sprays	26	66.67
29	Cultural practice practices for Pest and Disease Management	30	76.92
30	Time of harvesting	28	71.79

Table 6: Distribution of respondents according to Adoption levels

Sr	Adoption	Number	Per Cent	Mean	Standard Deviation
1	Low	05	12.82	16.67	5.48
2	Moderate	26	66.67		
3	High	08	20.51		

Table 7: Average yield of tomato varieties

Sr No	Particulars	Vinayak (T_1)	Arka Rakshak (T_2)	Arka Samrat (T_3)
1	Average Yield	450.83	520.83	492.33
2	Standard Deviation in Average yield	79.21	106.73	94.61

Derived measure — Coefficient of Variation (CV) (SD/Mean × 100):

- Vinayak CV = 17.6%
- Arka Rakshak CV = 20.5%
- Arka Samrat CV = 19.2%

Table 8: Technological and Extension Gap in Adoption of Tomato cultivation

Sr No	Particulars	Value
A	**Gap**	
1	Average Extension Gap (q/ha)	70.00
2	Average Yield Increase over Farmers Practice (%)	15.08
3	Average Technology Gap (q/ha)	279.17
4	Average Technology Index	34.86
B	**Standard Deviation**	
1	Standard Deviation in Extension Gap	29.55
2	Standard Deviation in Yield Increase over Farmers Practice	4.68
3	Standard Deviation in Technology Gap	106.73
4	Standard Deviation in Technology Index	13.28

Table 9: Economics of Tomato cultivation

Sr No	Particulars	Vinayak (T_1)	Arka Rakshak (T_2)	Arka Samrat (T_3)
A	**Economic parameters**			
1	Gross Cost (Rs./ha)	83123.33	81526.67	81526.67
2	Gross Return (Rs./ha)	251966.67	289853.33	275438.33
3	Net Return (Rs./ha)	168843.33	208326.67	193911.67
4	BC Ratio	3.03	3.54	3.37
B	**Standard Deviation**			
1	Standard Deviation in Gross Cost	4212.68	4288.61	4288.61
2	Standard Deviation in Gross Return	14963.13	28339.12	22333.01
3	Standard Deviation in Net Return	10767.25	24242.50	18079.93
4	Standard Deviation in BC Ratio	0.03	0.18	0.10

Derived Coefficient of Variation (CV)

- **Gross return CV:** T_1 = 5.94%; T_2 = 9.78%; T_3 = 8.11%
- **Net return CV:** T_1 = 6.38%; T_2 = 11.64%; T_3 = 9.32%
- **B:C ratio CV:** T_1 = 0.99%; T_2 = 5.08%; T_3 = 2.97%

Table 10: Descriptive Statistics

Variety	Mean yield (q/ha)	SD	CV (%)	Min	Max
T_1 (Vinayak)	450.79	87.42	19.39	280	594
T_2 (Arka Rakshak)	526.41	107.50	20.42	315	695
T_3 (Arka Samrat)	491.41	100.52	20.46	290	645

Table 11: One-Way ANOVA

Source	DF	F	p-value
Between Varieties	2	**5.72**	**0.0043 (significant at $p < 0.01$)**

Table 12: Tukey HSD pairwise comparisons of mean yield (q ha⁻¹)

Comparison	Mean Diff.	95% CI Lower	95% CI Upper	p-adj	Significance
T_1 - T_2	-75.6	-126.8	-24.4	0.003	Significant
T_1 - T_3	-40.6	-91.8	10.6	0.167	NS
T_2 - T_3	35.0	-16.2	86.2	0.247	NS

Conclusion

1. Respondents were progressive, motivated, and risk-taking, with moderate landholding and exposure to extension.
2. Adoption was higher for visible practices (transplanting, fertigation) than knowledge-intensive practices (nutrient doses, spacing, variety traits).
3. Technology and extension gaps are substantial, suggesting the need for frequent KVK visits, demonstrations, and capacity building.
4. Varietal adoption and recommended practices significantly increased yield (T_2 > T_3 > T_1) and profitability (highest net return and B:C ratio for T_2).
5. There exists a moderate to high technology and extension gap, which limits the potential yield and adoption of best practices. Targeted training, frequent KVK visits, and demonstration plots can reduce this gap.
6. Adoption of improved varieties, particularly Arka Rakshak, along with recommended practices, leads to substantial net returns and higher profitability, highlighting the importance of integrating technological interventions with extension support.
7. These findings suggest that while recommended technologies significantly enhance productivity, substantial potential remains unexploited due to suboptimal fertilizer management, pest control, and irrigation scheduling. Focused training on fertigation and organic matter application practices with moderate adoption levels in this study could further narrow the technology gap.
8. Statistical validation confirms that varietal choice significantly influences yield under on-farm conditions; Arka Rakshak provides the highest and statistically distinct advantage over the farmer-practice hybrid.
9. The mean technology gap was 279 q ha⁻¹, while the extension gap was 70 q ha⁻¹, corresponding to a yield increase of 15.1%. These findings suggest that while recommended technologies significantly enhance productivity, substantial potential remains unexploited due to suboptimal fertilizer management, pest control, and irrigation scheduling.
10. Arka Rakshak (T_2) provided the highest gross return (₹ 289,853 ha⁻¹) and net return (₹ 208,327 ha⁻¹) with a B:C ratio of 3.54, followed by Arka Samrat (3.37) and Vinayak (3.03). Thus, Arka Rakshak (T_2) is the most suitable variety for high yield and profit under local conditions.

Implications

1. Focused interventions are needed in areas with high technology gaps — such as nutrient management, spacing, and pest/disease control — to maximize adoption and minimize yield losses.
2. Demonstration of Arka Rakshak under farmer management, coupled with nutrient-management training and timely pest monitoring, can bridge existing yield gaps.
3. High adoption potential exists among moderate adopters already showing good knowledge and risk orientation; extension agencies can leverage this group to drive diffusion.
4. Farmers should be encouraged to adopt high-yielding varieties (T_2), proper spacing, fertigation, and pest management practices to reduce the technology gap and enhance returns.
5. Extension programs should focus on knowledge-intensive practices, provide soil test-based nutrient recommendations, and emphasize integrated pest management to optimize yields and fruit quality. Continuous reinforcement through on-farm demonstrations and KVK farmer field visits is critical for closing the remaining adoption gaps.
6. Soil fertility management, precise spacing, preventive pest/disease management, and variety selection were the high extension focus areas

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