***Original Research Article***

**Trend Analysis of Tomato Arrivals and Modal Prices at Gudumalkapur Market, Telangana**

**ABSTRACT**

**Aim:** The aim of this study is to examine how the daily supply (arrivals) and market prices (modal prices) of tomatoes have changed over time in the Gudumalkapur market of Telangana from 2019 to 2023 by using different statistical methods. This will help understand the market better and support decisions to improve price stability for farmers and consumers. (**Add a specific idea about the issue raised by the topic).**

**Study Design:** This study follows a quantitative research design aimed at analysing long-term trends in daily tomato arrivals and modal prices in the Gudumalkapur market of Telangana, India.

**Place and Duration of Study:** The study was conducted in Gudumalkapur market of Telangana, India, using arrivals and modal price data from 2019 to 2023.

**Methodology:** Daily tomato arrival and modal price data from Gudumalkapur market, Telangana, were analysed using non-parametric techniques like the Mann-Kendall test, Sen’s Slope estimator, and Innovative Trend Analysis. These methods effectively captured both long- and short-term trends, providing a robust assessment of market stability and price volatility.

**Results:** The results showed that tomato arrivals exhibited a significant increasing trend, as confirmed by the MMK and ITA, with a Sen’s slope of approximately 0.50 quintals per day. In contrast, modal prices displayed high short-term fluctuations but no significant long-term trend. Descriptive statistics revealed that arrivals were relatively stable (CV: 34.44%), while modal prices were highly volatile (CV: 102.40%). These findings suggest that while tomato supply to the market has improved consistently, price behavior remains unpredictable, likely influenced by external and short-term factors. These insights highlight the need for better market forecasting tools and price stabilization policies to support both farmers and consumers.

**Conclusion:** The study revealed a significant increasing trend in daily tomato arrivals at the Gudumalkapur market from 2019 to 2023, indicating improved and consistent supply. However, modal prices showed high short-term fluctuations without a clear long-term trend, highlighting persistent market volatility. These findings emphasize the need for effective price forecasting tools and stabilization strategies to support both farmers and consumers.

**Keywords**

*Tomato arrivals, Modal prices, Trend analysis, Gudumalkapur market, Modified Mann-Kendall test, Price volatility.*

**1. INTRODUCTION**

Tomato (*Solanum lycopersicum L*.) is one of the most important horticultural crops in India, widely cultivated and consumed due to its high nutritional value and versatile use in culinary preparations. It is rich in vitamins A and C, lycopene, and other antioxidants, playing a significant role in promoting food security and nutrition across diverse dietary systems. The crop is grown extensively across various agro-climatic regions of India, particularly in states like Andhra Pradesh, Maharashtra, Karnataka, Uttar Pradesh, and Madhya Pradesh. Despite its importance, tomato cultivation faces significant market-related challenges, primarily due to the crop’s high perishability, seasonal production cycles, and sensitivity to climatic fluctuations. These characteristics contribute to extreme price volatility, which in turn affects both consumers and producers. Unstable prices discourage investments in production and infrastructure and lead to income uncertainty for farmers. The issue is further complicated by inadequate storage facilities, inefficient supply chains, and inconsistent market access. Price volatility in tomatoes is more acute than in many other commodities due to inherent demand-supply mismatches, short shelf-life, and low-price elasticity of demand. **(But what about the relationship between tomato quality and cost? This factor particularly influences the selling price of a product. Such as periods of scarcity and high production. All these factors must be taken into account to justify better this idea.).** Compared to manufactured goods, agricultural commodities exhibit greater price fluctuations, stemming from their biological production constraints and susceptibility to external shocks (Acharya, 2001). This instability adversely impacts farmer incomes, disrupts market planning, and creates inefficiencies across the supply chain (Chand, 2003). Key reasons for this volatility include variability in annual production, weather dependencies, and the absence of real-time market information (Gulati *et al*., 2014 and Sharma and Kumar, 2022). **(As well as the cost of inputs used for production)**

To address these issues, there is a pressing need to analyze daily price and arrival patterns in wholesale markets. Understanding these dynamics helps in forecasting price trends, improving market intelligence systems, and supporting policy interventions aimed at price stabilization. Such analyses are essential for enabling farmers to make informed marketing decisions and secure better price realizations. In the present study, we conducted a comprehensive trend analysis of tomato arrivals and modal prices at the Gudimalkapur market, one of the important tomato markets in Telangana. We employed advanced non-parametric statistical techniques such as the Mann-Kendall trend test, Sen’s slope estimator, Modified Mann–Kendall test, and Innovative Trend Analysis (ITA) to detect and quantify trends in the time series data. These methods are well-suited for handling non-linear, non-stationary, and non-normally distributed datasets, which are typical of agricultural market data. The findings aim to provide insights that can support evidence-based decision-making for farmers, traders, market planners, and policymakers involved in tomato value chains.

**2. MATERIAL AND METHODS**

**2.1 Study Area**

In the present study, data on daily arrivals and prices of tomato was collected from January 2019 to December 2023 from the Agmarknet portal (<https://agmarknet.gov.in>) for Gudumalkapur market of Telangana, the most prominent vegetable markets in the state.

**(Describe how you collected the data. Was it randomly at several points in the market?**

**On the other hand, did you stay in one place to collect it?**

**What was the size, number, or quantity of your sample collected during this period?).**

The variability in tomato prices was studied by deploying different trend analysis methodologies. The collected data were organized, evaluated, and statistically analysed to identify and understand long-term trends. The analysis focused on capturing seasonal and annual patterns in tomato arrivals and price fluctuations over the time period.

**2.2 Trend analysis**

A trend refers to a consistent pattern or direction observed in a time series dataset, which may either be increasing (positive) or decreasing (negative) over time. Trends can be identified using both parametric and non-parametric statistical methods. We have used a combination of parametric and non-parametric techniques to analyse the data. These methods include Mann-Kendall Test, Sen’s Slope Estimator, Modified Mann-Kendall Test and Innovative Trend Analysis. Each of these methods are described in detail as follows.

**2.2.1 The Mann–Kendall’s trend Test**

The Mann-Kendall non parametric test is used to identify the significance of trends in the time series data (Bellamkonda *et al*., 2022 and Surendran *et al*., 2019). The trend may or may not be linear in different cases (Bellamkonda *et al*., 2022). The MK test detects monotonic trends (increasing or decreasing) without assuming any specific distribution of the data. The MK test can be expressed mathematically as

Let $x\_{1},x\_{2},x\_{3}…………….x\_{n} $represent *n* observations over time, where $x\_{j}$​ denotes the value at time *j*. The Mann–Kendall statistic *S* is defined as [4]:

$S=\sum\_{i=1}^{n-1}\sum\_{j=i+1}^{n}sgn(x\_{j}-x\_{i})$ (1)

Where the sign function is given by:

$sgn\left(x\_{j}-x\_{i}\right)=\left\{\begin{array}{c}+1 if x\_{j}-x\_{i}>0\\0 if x\_{j}-x\_{i}=0\\-1 if x\_{j}-x\_{i}<0\end{array}\right.$$ SEQ Equation \\* ARABIC $$1$ (2)

Here, ​$x\_{i}$ and $x\_{j} $are the values in years *i* and *j*, with *j > i*, and *n* is the total number of observations. The statistic *S* represents the difference between the number of positive and negative value pairs across all data points.

For datasets with a large sample size *(n>10),* the distribution of *S* can be approximated by a normal distribution, and the standardized test statistic $Z\_{mk} $is used. The mean and variance of *S* are given as:

$E\left(S\right)=0$ (3)

$Var\left(S\right)=\frac{n\left(n-1\right)\left(2n+5\right)-\sum\_{p=1}^{q}t\_{p}\left(t\_{p}-1\right)\left(2t\_{p}+5\right)}{18}$ (4)

where *q* is the number of tied groups in the data,$t\_{p}$ is the number of data points in the *pth* tied group. The standardized test statistic $Z\_{mk}$​ is then computed as:

$Z\_{mk}=\frac{s-1}{\sqrt{var\left(s\right)}} if s>0$ (5)

$$ =0 if s=0$$

 $=\frac{s-1}{\sqrt{var\left(s\right)}} if s<0$ (6)

This standardized statistic ​$Z\_{mk}$ follows the standard normal distribution under the null hypothesis. A positive $Z\_{mk}$​ value indicates an increasing trend, whereas a negative $Z\_{mk}$​ value suggests a decreasing trend. **(it should be noted that the Mann-Kendall test does not indicate the direction of the trend (upward or downward) but provides a result called the p-value that assesses the probability that the observed trend is real).** The null hypothesis of no trend is rejected if the absolute value of ​ $Z\_{mk} $exceeds the critical value of the standard normal distribution at the chosen significance level α: $\left|Z\_{mk}\right|\geq Z\_{1}{α}/{2}$.

* + 1. **Sen’s slope estimator**

The Sen's slope serves as a valuable tool for detecting the strength of a trend within a dataset devoid of serial autocorrelation (Preethi *et al*., 2024). This method is particularly useful when the underlying trend can be assumed to be approximately linear over time. The Sen’s slope can be expressed mathematically as $Let f\left(t\right)=Qt+B$ a time series,where *Q* is the slope of the trend, *B* is a constant and, *t* is time. To estimate the slope *Q*, Sen’s method calculates the slopes of all possible pairs of data points using the following formula:

$Q\_{i}=\frac{x\_{j}-x\_{k}}{j-k} for all j>k$ (7)

where $x\_{j}$ and $x\_{k}$ are the data values at time points *j* and *k* respectively. If the time series contains *n* observations, a total of $N= \frac{n\left(n-1\right)}{2}$ slope estimates $Q\_{t}$ will be computed. The Sen’s slope estimate *Q* is then calculated as the median of these​ $Q\_{i}$ values:

$Q=\left\{\begin{array}{c}Q\_{\left(\frac{n+1}{2}\right)} if N is odd\\\frac{1}{2}\left[Q\_{\left(\frac{n}{2}\right)}+Q\_{\left(\frac{n+1}{2}\right)}\right] if N is even\end{array}\right.$ (8)

To estimate the intercept *B* in $f\left(t\right)$, the values of $x\_{i}-Q\_{ti} $are computed for all *i*, and the median of these values is taken as the estimate of *B*. The method is robust and provides a reliable estimate of trend magnitude, even in the presence of missing values or outliers.

**2.2.3 Modified mann-kendall test**

The modified Mann-Kendall trend test serves as a robust non-parametric statistical tool utilized for identifying trends within time series data. Its primary function is to detect monotonic trends, whether they are increasing or decreasing, over time (Laasya *et al*., 2024). This method enhances the reliability of the traditional (MK) test by addressing the issue of serial correlation through a variance correction approach. The corrected variance of the MK statistic *S* in the MMK test is defined as:

 $V^{\*}\left(S\right)=V\left(S\right)\frac{n}{n^{\*}}$ (9) [7]

where $\frac{n}{n^{\*}}$ is a correction factor.$V\left(S\right)$is calculated as in the original MK test. The null hypothesis (Ho) assumes that there is no trend in the time series. The test statistic is then standardized using the corrected variance, and the null hypothesis is rejected if Z transformed value exceeds the Z critical value at a given significance level $(\left|Z\_{mk}\right|\geq Z\_{1}{α}/{2}$).

* + 1. **Innovative Trend analysis**

The Innovative Trend Analysis (ITA) is an advanced approach to identifying trends in time series data. Unlike traditional methods, ITA splits the data into two equal halves and plots them in increasing order (Ali and Abubaker ,2019). It offers a novel approach for trend detection by splitting time series data into two parts and analysing them on a Cartesian plane (Laasya *et al*., 2024) In this method, the first half of the time series is plotted along the X-axis, while the second half is plotted along the Y-axis. The resulting scatter plot aids in visualizing the trend: points lying above the 1:1 line suggest an increasing trend, whereas those below indicates a decreasing trend. This technique, known as the Integrated Trend Method is particularly effective for identifying subtle trends that may be overlooked by traditional methods.

The trend indicator, denoted as D, is computed using the following equation:

 $D=\frac{1}{2n}\sum\_{i=1}^{n}\left(Y\_{j}-μ\right)$ (10) [8]

where $Y\_{i}$, $Y\_{j}$ are the corresponding data points from the first and second halves of the time series, respectively, $μ$ is the mean of the first half of the series and *n* is the number of data points in each half.

**3. RESULTS AND DISCUSSION**

To understand the overall behaviour of tomato prices and arrivals at the Gudumalkapur market, we performed descriptive statistical analysis (Table 1). It was observed that the average daily modal price of tomatoes during the study period was rupees 1,360.87 per quintal, while the average daily arrival was 1,647.49 quintals. This suggests that the market maintained a reasonably steady supply of tomatoes on most days, accompanied by moderately high price levels. However, modal prices revealed considerable variability, with a coefficient of variation (CV) of 102.40%, as compared to 34.44% for arrivals. This indicates that while arrivals were relatively stable, prices fluctuated widely throughout the period. The standard deviation of prices (rupees 1,393.49) was also significantly higher than that of arrivals (567.40 q), reinforcing the observation of high price volatility. The price range spanned from rupees40 to rupees 12,000 per quintal, indicating extreme spikes, while arrivals ranged from 143 to 4,054 q/day, showing a more controlled and predictable supply pattern. The large sample variance and high standard error in price data further suggest that tomato prices were highly unpredictable, potentially due to demand-supply imbalances, seasonal surges, and external disruptions such as extreme weather events or logistical inefficiencies. Similar volatility trends have been documented in other agricultural contexts where climatic variability and market imperfection amplify uncertainties in agricultural commodity pricing (Bellamkonda *et al.,* 2022; Surendran *et al*., 2019). This analysis underscores the need for robust price forecasting models and better post-harvest infrastructure to buffer against such unpredictable spikes.

* 1. **Trend of Daily Tomato Arrivals and Modal Prices**

The Fig.1 represents the trend of daily tomato arrivals and modal prices at the Gudumalkapur market from January 2019 to December 2023. Overall, daily arrivals remained relatively stable throughout the period, with minor seasonal fluctuations. (**Could this justify an almost permanent supply of tomatoes to the markets?)** In contrast, modal prices showed significant variability, with frequent sharp peaks and drops, indicating high price volatility. **(In fact, apart from the factors mentioned above, price variability despite the availability of tomatoes on the market could also be explained by variability in the quality of tomatoes sold. Producers or production, storage, and transport conditions could significantly influence the quality of tomatoes placed on the market. In other words, the trend in tomato prices on the market may not be only related to quantity or permanent availability on the market during the period covered by this study).**

The arrivals remained relatively stable with seasonal variations, while modal prices exhibited high volatility, marked by frequent spikes. A notable surge in prices occurred between May and August 2023, peaking around Rs.12,000/q, despite no significant drop in arrivals. This demonstrates that factors like climate events, logistics issues, or market speculation may have driven the price surge **(As mentioned above).** After August 2023, prices quickly stabilized, indicating a temporary disruption. Over the five-year period, price trends were far more unstable than arrivals, highlighting an asymmetric relationship between supply and pricing. These insights emphasize the need for better market forecasting tools, price stabilization strategies, and timely dissemination of market information to reduce uncertainty for farmers and consumers alike.

**Table 1. Descriptive statistics of daily tomato modal prices and arrivals at Gudumalkapur market (2019–2023)**

|  |  |  |
| --- | --- | --- |
| Parameter | Modal Price | Arrivals |
| Mean | 1361 | 1647 |
| Standard Deviation | 1393 | 567 |
| Coefficient of Variation (CV) | 102 | 34.44 |
| Minimum | 40 | 143 |
| Maximum | 12,000 | 4,054 |
| Standard Error | 32.61 | 13.28 |
| Sample Variance | 19,41,810 | 3,21,939 |

Moreover, although the supply of tomatoes was consistent over the period, the price instability could significantly impact both producers **(but more about consumers, who are also the buyers.),** exposing them to market risks. **(In light of this situation, understanding the trend remains a major asset in controlling the variability of tomato prices on the market).** This aligns with observations by Ali and Abubaker (2019) and Hamed and Rao (1998), who emphasized the importance of trend detection in agricultural time series to inform risk management and policy support systems.

* 1. **Trend Analysis Using MMK Test and Sen’s Slope**

The Fig.1&2 represents the trend of daily tomato arrivals and modal prices at the Gudumalkapur market from January 2019 to December 2023. Overall, arrivals remained relatively stable with seasonal fluctuations. In contrast, modal prices were highly erratic, with frequent sharp peaks and drops, indicating significant market volatility. A notable surge in prices was recorded between May and August 2023, peaking at rupees12,000/q, despite no substantial drop in arrivals.

This divergence highlights the influence of non-supply factors such as adverse weather events, transportation disruptions, or speculative hoarding practices on price surges. A rapid correction in prices post-August suggests the temporary nature of the disruption, but such fluctuations still pose a risk to both producers and consumers. As pointed out by Laasya *et al.* (2024) and Vakapalli *et al.* (2024), incorporating climatic and infrastructural variables into trend models can offer better explanatory power for such erratic price behaviour.These insights highlight an asymmetric relationship between supply and price, necessitating targeted interventions like storage expansion, early warning systems, and real-time market intelligence platforms to protect **(and raise awareness)** stakeholders and improve price realization.

* 1. **Trend Analysis Using MMK Test and Sen’s Slope (why that title again?)**

The Modified Mann-Kendall (MMK) test results (Table 2) revealed a statistically significant increasing trend in daily tomato arrivals at the Gudumalkapur market (Z = 11.81, p < 0.00001). The Sen’s slope estimates of 0.497 indicates a steady average increase of approximately 0.5 q/day over the five-year period. **(What exactly does that mean in this case?)**. This trend is consistent with findings from previous long-term agricultural trend studies (Preethi, *et al.,* 2024; Bellamkonda *et al.,* 2022), which also reported significant upward trends in climatic and production-related variables using similar non-parametric methods.

In contrast, modal prices did not exhibit a statistically significant trend (Z = 0.69, p = 0.49), and the Sen’s slope was relatively low (0.107), indicating an absence of consistent upward or downward movement in price levels. This suggests that although the supply of tomatoes is gradually increasing, market prices remain susceptible to short-term variations rather than long-term systematic shifts. The findings reiterate that price dynamics are influenced more by short-term shocks and demand fluctuations than by structural changes in supply. **(Does any author justify this idea? If so, please mention it).**

**Table 2. Modified Mann-Kendall test of trend analysis for daily tomato arrivals and modal prices (2019–2023)**

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Z-Transformed Test Statistic | Trend | Sen’s Slope |
| Arrivals | 11.81 | \* | 0.497 |
| Modal Price | 0.69 | NS | 0.108 |

NS – Non-significant trend; \* – Significant trend

* 1. **Innovative Trend Analysis**

Innovative Trend Analysis (ITA) results (Table 3) further confirmed a strong and consistent increasing trend in tomato arrivals, with a trend slope of 0.491 and a high correlation coefficient (0.995). This strong linear association reflects structural improvements in tomato production and/or market access over the study period. (**Before asking an author to confirm your analysis, please analyze, interpret, and explain this result in the context of your study).** These results are in line with recent agricultural trend assessments where ITA successfully captured hidden monotonic trends often missed by classical techniques (Ali and Abubaker, 2019).

In contrast, modal prices demonstrated a higher slope (0.657) but with wide confidence intervals crossing zero, and a relatively lower correlation (0.871), suggesting a weak and statistically uncertain trend. This implies that prices are heavily influenced by short-lived disruptions and lack a predictable long-term direction **(Good).** Such findings support the growing consensus that agricultural price trends must be interpreted with caution and in conjunction with contextual factors like climatic anomalies, transportation constraints, and consumption shocks **(Good).** Therefore, incorporating multi-source data, including weather, input costs, and demand patterns, could enhance the robustness of trend interpretations (Surendran *et al*., 2019; Hamed & Rao, 1998).

**Table 3. (ITA) of daily tomato arrivals and modal prices at Gudumalkapur market (2019–2023)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Parameter | Trend Slope | Trend Indicator | Correlation | Slope SD | α = 0.10 | α = 0.05 | α = 0.01 |
|  |  |  |  |  | LCL | UCL | LCL |
| Arrivals | 0.491 | 3.15 | 0.995 | 0.0015 | -0.0025 | 0.0025 | -0.003 |
| Modal Price | 0.657 | 5.65 | 0.871 | 0.0181 | -0.0298 | 0.0298 | -0.0356 |

**4. CONCLUSION**

This study analysed the trends in daily tomato arrivals and modal prices at Gudimalkapur market over a five-year period using descriptive statistics, trend plots, the Modified Mann-Kendall test, Sen’s slope, and Innovative Trend Analysis. The descriptive analysis revealed that arrivals remained relatively stable, whereas modal prices exhibited considerable volatility, with high variability observed across the dataset. Trend visualization confirmed frequent price spikes, notably a sharp surge during the middle of the final year, while arrivals followed a more seasonal and consistent pattern. The results from the Modified Mann-Kendall test and Sen’s slope indicated a statistically significant increasing trend in arrivals. In contrast, modal prices did not show any clear long-term trend despite experiencing short-term fluctuations. These observations were further validated by Innovative Trend Analysis, which confirmed a strong upward pattern in arrivals and a weak, inconsistent trend in modal prices.

The study highlights that the supply of tomatoes to the Gudumalkapur market has been steadily increasing over time. However, modal prices remain volatile and do not follow a consistent long-term trend, likely due to short-term market disruptions, climatic variability, and fluctuating demand. **(There is no correlation between the price of tomatoes at the study site market and supply. Other factors, which remain to be identified, could be controlling the variability of tomato prices at the market).** These findings underscore the need for enhanced price stabilization strategies, improved forecasting systems, and timely dissemination of market information to safeguard stakeholders and enhance market efficiency.

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**Fig. 1. Trend of** **daily tomato arrivals (2019–2023) (Modal price based on time)**

**Fig. 2. Trend of** **daily tomato modal prices (2019–2023) (Trend of daily tomato modal price based on time)**