Agric Res J **60** (4) : 614-620, *August* 2023
DOI No. 10.5958/2395-146X.2023.00087.X

PRICE DYNAMICS AND VOLATILITY IN TOMATO MARKET IN INDIA

Amit Guleria[1], Pardeep Singh[2*] and Laishram Priscilla[1]

[1]Department of Economics & Sociology, Punjab Agricultural University, Ludhiana-141004, Punjab and [2]ICAR-National Institute of Agricultural Economics and Policy Research, Pusa, New Delhi-110012

ABSTRACT

This paper analyzed the price dynamics and volatility among tomato-producing (Solan and Ludhiana) and consuming (Delhi and Bangalore) markets using monthly price data from April 2005 to March 2023. The Cudda Della-Valle index and seasonality index were used to assess the price dynamics of the tomato market. Correlation analysis, Regression analysis, Vector Error Correction Model, and Granger causality were used to analyze the market integration. The GARCH model is used to measure the price volatility in the selected markets. Results showed that the maximum instability in tomato prices was in May (53 to 77 %), and the seasonality index showed that farmers received more than average prices between July and November. The significance of the Engle-Granger tau-statistic revealed that all the selected markets were well integrated into the long run. The speed of adjustment was highest in the Delhi market (56 %) followed by Bangalore (55 %) and Solan (27 %). The Bangalore market was the key market that influenced the price of all other markets by the Granger Causality test. Further, GARCH (1,1) model is used to estimate price volatility in the selected market. The price volatility was high in the Solan market and low in all the selected markets.

Keywords: GARCH, Instability, Market integration, Volatility

Due to its diversified soil and climate, India has ample scope to cultivate a range of horticulture crops (Singh *et al.,* 2022a, b). With an area of over 14 percent and a share of nearly 37 percent in all agricultural exports, the horticulture sector contributes 30 percent to the total agricultural GDP (GoI, 2022). Keeping in mind the significance of such crops in the economy, the central government launched “Operation Greens”, a programme for integrated development of the Tomato, Onion, and Potato (TOP) value chain in 2018–19 (Government of India 2019). The main goal of the programme was to stabilize prices since vegetable crops, because of the weather-sensitive and cyclical nature of production, have relatively high price volatility compared to other crops. Of these three crops, tomatoes are known for having the most volatile prices. Tomato price fluctuation can be related majorly to its perishable nature, among other factors like weather patterns, supply-demand dynamics, problems with transportation and storage, and governmental regulations.

The market behavior of tomatoes in different regions of the country in the past has demonstrated that the produce continues to be a bone of contention for both growers and the government. Markets are geographically dispersed, yet prices show long-term spatial links between various market centers, indicating that all exchange locations are linked and that prices deliver pertinent market signals (Ghosh, 2010; Singh *et al.,* 2020; Kumar *et al.,* 2022). Studies have found that, in the case of tomato markets, the level of spatial market integration is relatively low, resulting in price differentials and higher price volatility (Kumar *et al.,* 2016; Kumar *et al.,* 2016; Singh and Mishra, 2018; Dey *et al*., 2019; Ankita *et al.,* 2021). This indicates that if markets are spatially integrated, the government can concentrate on stabilizing market prices in the impetus market, and the same signal will be communicated to the other markets.

Hence, understanding the dynamics of price behavior, market integration, and price volatility in the tomato market is crucial for policymakers, farmers, traders, and consumers. This research paper aims to contribute to this understanding by examining the co-movement of prices among different domestic markets for tomato crops in north India. It also aims to estimate the degree of market integration and measure the level of price volatility. This may help policymakers anticipate price movements and stabilize prices, which will benefit both consumers and producers by helping avoid sudden price shocks.

MATERIALS AND METHODS

The study is based on secondary data; collected from the Agmarknet portal of the Ministry of Agriculture and Farmers Welfare, Government of India. The monthly time series data on tomato prices and arrivals from April 2005 to March 2023 were analyzed to investigate market integration across four major wholesale markets: Solan (Himachal Pradesh), Ludhiana (Punjab), Azadpur

*Corresponding author : pardeepmahal1994@gmail.com
Date of receipt: 02.05.2023, Date of acceptance: 24.08. 2023

(Delhi), and Bangalore (Karnataka). These markets were selected based on their location and the volume of produce handled. Solan and Ludhiana are situated in tomato-producing regions (Babu, 2016; Singh, 2017; Singh *et al*., 2022c), while Delhi and Bangalore are located in consuming areas.

Statistical analysis

Different analytical tools such as seasonality analysis, unit root test, log-log regression analysis, Granger's causality analysis, vector error correction model, and GARCH model were used to examine the price dynamics and volatility. The analysis of data was performed by using Eviews 12 and R software.

Instability analysis

The coefficient of variation (C.V.) is used to estimate instability in time series data. However, a limitation of C.V. is that it overestimates the level of instability in the time series data characterized by long-term trends (Nimbrayan and Bhatia, 2019; Singh *et al.,* 2020a, b; Paul *et al*., 2013). This limitation is overcome by the Cuddy-Della Valle index (CDVI) suggested by Cuddy and Della Valle (1978), which corrects the coefficient of variation.

$$CDVI = CV\sqrt{1 - r^2}$$

where, r^2=coefficient of determination

Seasonality index

The range in seasonality was estimated by using the method suggested by Ali (2000):

S_i = *average of ith month* (I_a / I_e)

S_i = Seasonal indices

I_α = Actual value of price series

I_e = Estimated value of price series

Test for stationarity

Before conducting tests for co-integration and Granger causality in time series analysis, the initial step is to assess the stationarity of each individual time series included in the analysis. The Augmented Dickey-Fuller (ADF) unit root test (Dickey and Fuller, 1981) was employed to achieve this. The ADF test was utilized to determine the order of integration using the following model:

$$\Delta P_t = \alpha_0 + \delta_1 t + \beta_1 P_{t-1} + \sum_{j=0}^{q} \beta_1 \Delta P_{t-j} + \varepsilon_t$$

Where,

P = the price in each market,

Δ = difference parameter (i.e., $\Delta P_1 = P_t - P_{t-1}$, $\Delta P_{t-1} = P_{t-1} - P_{t-2}$ and $\Delta P_{n-1} = P_{n-1} - P_{n-2}$

α_0= constant or drift

t = time trend variable

q = number of lag length and

ε_t = pure white error term,

The null hypothesis is that β_1 (the coefficient of P_{t-1}) is zero. The alternative hypothesis is: $\beta_1 < 0$. A non-rejection of the null hypothesis suggests that the time series under consideration is non-stationary (Gujarati, 2010).

Log-log regression model

In order to estimate the long-run relationship between the markets, a log-log regression model was used in this study. The coefficient of the model gives the percentages. The functional form of the model is given below.

$LnY_t = \beta_0 + \beta_1 LnX_1 + \beta_2 LnX_2 + \beta_3 LnX_3$

Where Y_t is the dependent market and X_1, X_2, X_3 are the independent markets

β_0 is the intercept and β_1, β_2, and β_3 are the elasticity coefficients.

Engle-Granger tau-statistic was also estimated in order to find the significance of long-term relationships in Eviews (Guleria *et al.,* 2023).

Vector error correction model

After establishing the long-term relationship, then the next step is to find the short-run relationship along with the speed of adjustment towards equilibrium using the error correction model, represented by equations:

$$\Delta lnX_t = \propto_0 + \sum \beta_{1i}\, \Delta lnY_{t-i} + \sum \beta_{2i}\, \Delta lnX_{t-i} + \gamma ECT_{t-1}$$

$$\Delta lnY_t = \beta_0 + \sum \propto_{1i}\, \Delta lnX_{t-i} + \sum \alpha_{2i}\, \Delta lnY_{t-i} + \gamma ECT_{t-1}$$

where ECT_{t-1} is the lagged error correction term; X_t and Y_t are the variables under consideration transformed through natural logarithm; and X_{t-l} and Y_{t-i} are the lagged values of variables X and Y. The parameter γ is the error correction coefficient that measures the response of the regressor in each period to departures from equilibrium. The negative and statistically significant values of γ depict the speed of adjustment in restoring equilibrium after disequilibria, and if it is positive ad zero, the series diverges from equilibrium.

Granger causality test

To examine the presence and direction of a long-term causal price relationship between markets, the Granger causality test is performed using a VAR model (Granger, 1969). The F-test is utilized to evaluate the significance of any alterations in one price series on another price series (Gujarati, 2010). Moreover, this test identifies the crucial market that has an impact on the prices of all other markets.

Measuring price volatility: The ARCH family model

Volatility is a term used to describe the potential range of outcomes for an uncertain variable. Typically, this is measured using the sample standard deviation or variance, which quantifies the variability in returns over a certain time period. Volatility is commonly used to assess the overall risk of financial assets and is often incorporated into Value-at-risk models to gauge market risk. The level of volatility can be estimated by examining the sum of α and β, which are values derived from the ARCH and GARCH models, respectively. A sum of $\alpha+\beta$ of 1 or greater indicates high volatility, which can result in sudden and significant fluctuations in asset prices. In contrast, a sum of $\alpha+\beta$ less than 1 suggests low volatility, with changes in prices occurring less frequently and persisting over a longer period. It is important to note that while volatility is a commonly used measure of risk, it is not the only factor to consider when assessing potential investment outcomes.

RESULTS AND DISCUSSION

This section deals with the analysis of price dynamics by seasonality and instability indices. The long-term and short-term relationship between the selected markets was estimated by the log-linear model, vector error correction model, and Granger Causality test. Lastly, to measure the price volatility in the selected markets, the GARCH model was used.

Seasonality and instability analysis

Table 1 presents an analysis of the instability in tomato prices across the selected markets. The highest CDVI (Cuddy Della Vella Index) value was observed in May for all markets except Solan, where the highest CDVI value was recorded in June.

The lowest CDVI value was observed in March for the Solan and Ludhiana markets, in April for the Delhi market, and in February for the Bangalore market. The seasonality index was greater than one between July and November for all markets except Bangalore, where it was higher between May to July and October to December, indicating that farmers received prices above the average during these periods. Similar findings were reported by Shrestha and Huang (2014), who found that tomato prices exhibited high fluctuations, with high prices from June to October and low prices from January to April every year.

Correlation analysis

Table 2 displays the outcomes of the correlation analysis of monthly tomato prices in the chosen markets. The correlation coefficients between the markets were found to be highly significant, ranging from 0.62 to 0.94. These results indicate that tomato prices in these markets exhibited a strong and integrated movement. Moreover, the results suggest that the price differentials in the markets were not higher than the cost of transportation, indicating that the markets were efficient.

Table 1. Instability and seasonality in tomato price in selected markets

Month	Solan			Ludhiana			Delhi			Bangalore		
	CV	CDVI	SI	CV	CDVI	SI	CV	CDVI	SI	CV	CDVI	SI
January	48.42	30.67	0.88	37.89	27.95	0.91	41.07	35.37	0.76	61.43	51.83	0.91
February	43.08	30.56	0.94	37.96	24.86	0.79	36.67	28.88	0.69	57.78	39.70	0.63
March	35.67	26.12	0.97	34.69	22.41	0.81	35.44	28.39	0.75	55.95	46.71	0.60
April	44.86	29.71	1.05	40.49	23.26	0.84	38.76	28.24	0.72	54.59	45.59	0.78
May	65.41	53.05	0.72	59.01	45.48	0.55	68.56	57.80	0.53	87.15	76.78	1.22
June	65.20	54.19	0.87	50.85	43.97	0.71	65.93	55.78	0.83	69.59	59.73	1.34
July	50.24	39.90	1.17	41.00	29.84	1.28	41.93	33.88	1.44	66.74	61.01	1.25
August	49.89	39.71	1.05	42.67	31.63	1.33	44.94	39.57	1.36	82.12	75.51	0.82
September	54.42	38.17	1.06	45.18	32.58	1.16	42.72	34.33	1.32	52.65	41.75	0.88
October	53.42	29.56	1.17	45.54	24.45	1.25	44.66	25.40	1.41	57.45	43.59	1.08
November	69.40	53.89	1.19	54.79	42.47	1.34	60.45	49.38	1.30	72.58	67.39	1.33
December	68.28	46.49	0.90	47.34	34.53	1.04	54.10	43.01	0.85	73.44	66.77	1.15

CV-Coefficient of Variation (%), CDVI- Cuddy-Della Valle index and SI-Seasonality Index

Table 2. Correlation coefficients of Monthly Tomato Prices between selected markets

Markets	Solan	Ludhiana	Delhi	Bangalore
Solan	1.00			
Ludhiana	0.90*	1.00		
Delhi	0.86*	0.94*	1.00	
Bangalore	0.71*	0.62*	0.66*	1.00

*indicates p<0.05

Augmented Dickey-Fuller test (ADF)

Although correlation analysis provides an initial understanding of price movements, it may not be sufficient to establish market integration. Therefore, to obtain more accurate insights, advanced econometric techniques such as the Log-log regression model, Granger causality test, and vector error correction model were employed in this study. To ensure reliable results, it was crucial to verify the stationarity of the variables. Additionally, to establish a long-term equilibrium relationship among the price series, it was necessary to check for co-integration. If the variables have a unit root, co-integration is not possible, and the order of integration among the variables needs to be determined by conducting a stationarity test.

In order to determine whether the price series were stationary at their level, as well as their differences, the ADF-based unit root test procedure was conducted. The results presented in Table 3 reveal that the t-statistic value for all the markets was significant, indicating that the series were stationary and free from the effects of unit root. As a result, the analysis could proceed to determine the long term relationship.

Estimation of long-term relationship

Johansen Co-integration test was not used to find long-term relationships between selected markets because all the price series are stationary at level. Therefore, the Log-Linear form of the regression model is used to determine the long-term relationship between the selected markets in Table 4. The value of the Engle-Granger tau-statistic was found to be significant for all, indicating that selected markets were well integrated. As the results revealed that the Solan market has a positive and significant long relationship with Ludhiana and Bangalore markets. While a one percent change in the tomato prices of Solan and Delhi markets leads to a change in the Ludhiana prices by 0.371 and 0.561 percent, respectively. Delhi market has a positive and

Table 3. ADF test to check the stationary of the data

Market	At level		
	t-Statistic	p value	Stationarity
Solan	-6.90	0.00	Stationary
Ludhiana	-6.67	0.00	Stationary
Delhi	-7.73	0.00	Stationary
Bangalore	-6.32	0.00	Stationary

Table 4. Long-term relationship between selected markets

Particulars	Log(Solan)	Log(Ludhiana)	Log(Delhi)	Log(Bangalore)
Intercept	-0.013 (0.100)	0.352 (0.060)	-0.219 (0.085)	0.658 (0.203)
Log(Solan)	-	0.371* (0.036)	-0.020 (0.059)	0.584* (0.137)
Log(Ludhiana)	0.882* (0.087)	-	0.989* (0.061)	-0.268 (0.219)
Log(Delhi)	-0.027 (0.080)	0.561* (0.034)	-	0.458* (0.162)
Log(Bangalore)	0.135* (0.032)	-0.026 (0.021)	0.079* (0.028)	-
Engle-Granger tau-statistic	-8.296*	-10.290*	-9.378*	-14.443*

*indicates p<0.05

significant relationship with Ludhiana and Bangalore markets. Similarly, the Bangalore market also has a positive and significant relationship with Solan and Delhi markets.

Vector error correction model

Vector Error Correction Model (VECM) was employed to examine the short-term equilibrium among the selected tomato markets in this study. This model provides information about the speed of adjustment among the variables for achieving long-term equilibrium. To determine the appropriate number of lags in the VECM, the Akaike Information Criterion (AIC) was used, and a lag of two was selected for all the selected markets (Solan, Ludhiana, Delhi, and Bangalore) as it had the lowest AIC value. The error correction term was used to analyze the stability, endogeneity, and movement towards long-term equilibrium, which are indicators of market efficiency. Additionally, the study examined the short-term causality among the prices of selected markets to identify which market affects the price of the other markets.

Vector Error Correction Equations:

$\Delta \ln Solan_t = -0.269ECT_{t-1} - 0.384\Delta \ln Solan_{t-2} - 0.402\Delta \ln Ludhiana_{t-1} + 0.472\Delta \ln Delhi_{t-1} + 0.342\Delta \ln Delhi_{t-2}$

$\Delta \ln Ludhiana_t = 0.229ECT_{t-1} - 0.628\Delta \ln Ludhiana_{t-1} - 0.403\Delta \ln Ludhiana_{t-2} - 0.338\Delta \ln Solan_{t-2} + 0.745\Delta \ln Delhi_{t-1} + 0.470\Delta \ln Delhi_{t-2}$

$\Delta \ln Delhi_t = -0.557ECT_{t-1} + 0.604\Delta \ln Delhi_{t-1} + 0.420\Delta \ln Delhi_{t-2} - 0.341\Delta \ln Solan_{t-2} - 0.711\Delta \ln Ludhiana_{t-1} - 0.166\Delta \ln Bangalore_{t-2}$

$\Delta \ln Bangalore_t = -0.551ECT_{t-1} + 0.527\Delta \ln Bangalore_{t-1} - 0.210\Delta \ln Bangalore_{t-2} - 0.482\Delta \ln Solan_{t-2} + 0.464\Delta \ln Ludhiana_{t-2}$

When considering Solan markets as dependent on other markets, the speed of adjustment is generally low, at 27 percent, respectively. This may be due to the fact that these markets are said to be producing markets, supplying produce to other markets, with only one-way transactions. However, in Delhi and Bangalore markets, where they are found to be consuming markets, the speed of adjustment is higher at 56 percent and 55 percent, respectively. This faster error correction mechanism suggests that stored quantities may be released. Similar findings were reported by Saxcena and Chand (2017) in Lasalgaon and Solapur markets for onions, where they found one market to be a producing market and the other to be a consuming market.

The results revealed that there is a two-month lag effect of tomato prices in the Solan and Bangalore markets on the prices in the Delhi market. Additionally, the prices in Solan and Ludhiana markets have an impact on the prices in the Bangalore market, with a lag of two months. Moreover, the prices in the Ludhiana market are influenced by the prices in Solan and Delhi markets, with a lag of one or two months. Furthermore, the Wald test showed that short-run equilibrium exists among all the selected markets at lag one in the case of Solan.

Granger causality test

Table 5 and Fig. 1 present the results of the Granger Causality analysis on the price series of the selected markets. The analysis reveals that the tomato prices in the Bangalore market have a bidirectional causality transmission with the tomato prices in other markets. The Delhi market has a bidirectional relationship with the Bangalore and Ludhiana markets, meaning that it influences their prices and is also influenced by their prices. The Ludhiana market, on the other hand, has a

Table 5. Results of Granger causality test

Null Hypothesis	Observations	F-Statistic	p value
LUDHIANA does not Granger Cause SOLAN	215	1.407	0.247
SOLAN does not Granger Cause LUDHIANA		2.244	0.109
DELHI does not Granger Cause SOLAN	215	0.820	0.442
SOLAN does not Granger Cause DELHI		0.442	0.643
BANGALORE does not Granger Cause SOLAN	215	7.875	0.001
SOLAN does not Granger Cause BANGALORE		9.941	0.000
DELHI does not Granger Cause LUDHIANA	215	14.065	0.000
LUDHIANA does not Granger Cause DELHI		3.918	0.021
BANGALORE does not Granger Cause LUDHIANA	215	10.475	0.000
LUDHIANA does not Granger Cause BANGALORE		10.461	0.000
BANGALORE does not Granger Cause DELHI	215	6.504	0.002
DELHI does not Granger Cause BANGALORE		6.622	0.002

bidirectional relationship with the Delhi and Bangalore markets, while the Solan market only unidirectionally influences the Ludhiana market and has a bidirectional relationship with the Bangalore market. The analysis shows that the Bangalore market plays a key role in influencing the price of tomato crops in all other selected markets.

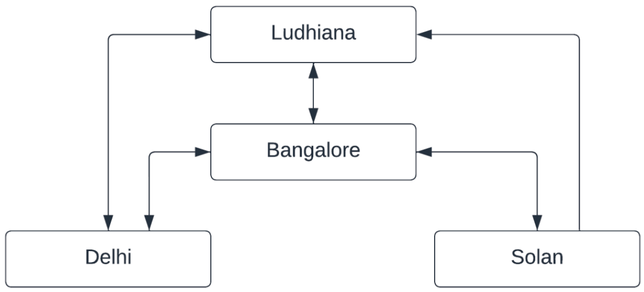

Fig. 1. Causation between prices of selected markets (Key market: Bangalore)

Testing the ARCH effect in the key market

The Box-Jenkins approach has a basic assumption that the residuals remain constant over time. Thus, the ARCH – Lagrange multiplier (LM) test was carried out on the square of the residuals and to test whether residuals do in fact remain constant. The result of ARCH-LM test is given in the Table 6. The results revealed that there was presence of volatility in all the selected markets.

Table 6. ARCH - LM test for price series of selected market

Markets	F statistic	p value	Volatility
Solan	55.97	p<0.01	Present
Ludhiana	60.81	p<0.01	Present
Delhi	28.52	p<0.01	Present
Bangalore	32.42	p<0.01	Present

Measuring price volatility

GARCH (1,1) is used to measure the extent of price volatility in the selected markets. The estimates of the parameters of GARACH (1,1) model were presented in Table 7. The parameter α of square of residuals at one lag in the model was significant for all the selected markets.

The high value of α indicates severe external shocks to the tomato markets. As the results indicates that the value of α is more than one for Solan market indicates that tomato prices in this market is strongly influenced by external factors other than price. However, the parameter β of variance at one lag was found negative and significant only for Bangalore market indicates own variance of this markets helps in observing effect of any price shock in the market. The value of α+ β for the Solan markets was found to be more than one, indicates this market is high volatile and effect of external forces were more in this market. The severity level of price volatility was low for all the other markets as value of α+ β was less than one.

The study revealed that tomato prices in the selected markets were unstable, particularly in May, and farmers received higher prices than the average during the months of July to November. Correlation analysis showed that market prices moved together and were well-integrated, implying that price differentials were not greater than transportation costs. The selected market prices were stationary at level, and regression analysis indicated that tomato prices had a long-term relationship. The Delhi market had the highest speed of adjustment (56%), followed by Bangalore (55%) and Solan (27%). The Granger causality test showed that Bangalore market was the most influential market in terms of affecting the prices of the other selected markets. GARCH model was used to estimate price volatility in the selected markets. Solan market was found to be highly price volatile as compared to other selected markets. Strengthening of cold storage infrastructure and create fully integrated supply chain so as to reduce the variation in arrivals and prices.

Table 7. Results of GARCH model

Market	Mean	Variance equation			Log likelihood	Volatility (α+β)	Severity level
		Intercept	ε^2_{t-1} (α)	σ^2_{t-1} (β)			
Solan	897.94	94005.13	1.22*	0.07	-1711.46	1.28	High
	(31.07)	(25294.14)	(0.19)	(0.06)			
Ludhiana	1198.30	208408.50	0.80*	-0.04	-1714.74	0.76	Low
	(42.66)	(59509.83)	(0.20)	(0.14)			
Delhi	961.12	211830.50	0.87*	-0.06	-1709.55	0.82	Low
	(35.99)	(27558.35)	(0.20)	(0.06)			
Bangalore	940.98	528457.50	0.48*	-0.15*	-1750.46	0.33	Low
	(70.65)	(53972.89)	(0.07)	(0.03)			

*p<0.05, Figure in parenthesis indicates standard errors

Authors' contribution

Conceptualization and designing of the research work (AG, PS), Data collection and data cleaning (AG, LP); Analysis of data and interpretation (AG, PS); Preparation of manuscript (PS, LP)

LITERATURE CITED

Ali M 2000. Dynamics of vegetables in Asia, a synthesis. In *Dynamics of vegetable distribution and consumption in Asia* (Mubarik Ali, ed.). Asian Vegetable Research and Development Centre, Shanhua, Taiwan. 29p.

Ankita, Singh P and Guleria A 2021. Value chain analysis of tomato in Himachal Pradesh: A case study of Kullu District. *Indian J Ecol* **48**: 411-17.

Babu G 2016. Price Behavior and Farmer Assessment in Functioning of Regulated Markets of APMC Solan district of Himachal Pradesh. M.Sc. Thesis. Department of Social Sciences. Dr. YSP UHF, Nauni, India. 71p.

Cuddy J D A and Della V P A 1978. Measuring of Instability of Time Series Data. *Oxf Bull Econ Stat* **40:** 79-85.

Dey M M, Bhattacharya S and Dey A 2019. Market integration, price transmission and volatility of tomato in India: Evidence from selected major wholesale markets. *Agric Econ Res Rev* **32:** 293-302.

Dicky D A and Fuller W A 1981. Distribution of estimators for autoregressive time series with unit root. *JASA* **336**: 427-31.

Ghosh M 2010. Spatial price linkages in regional food grain markets in India. Margin: *J Appl Econ* **4:** 495-516.

GOI 2022. National Horticulture Board Annual Report 2021-22, Ministry of Agriculture & Farmers Welfare, Govt. of India.

GOI 2019. Ministry of Food Processing Industries issues guidelines for operation greens, Press Information Bureau, Ministry of Food Processing Industries, New Delhi. http://www.pib.nic.in/Pressreleaseshare.aspx?PRID=1551889.

Granger C W J 1969. Investigating causal relations by econometric models and cross- spectral methods. *Econometrica* **37**: 424-438.

Gujarati D 2010. Econometrics by Example. Macmillan Publishers, London. 416p.

Guleria A, Kaur K and Sachdeva J 2023. Assessment of co-integration among kinnow markets in India. *Indian J Economics Dev* **19:** 102-111.

Kumar P, Singh R and Singh J 2016. Price behaviour and market integration of tomato in India: A study of select markets in North India. *Agric Econ Res Rev* **29:** 265-76.

Kumar S, Arora K, Singh P, Gupta A K, Sharma I and Vatta K 2022. Performance comparison of ARIMA and Time Delay Neural Network for forecasting of potato prices in India. *Agric Econ Res Rev* ***35*****:** 119-34. DOI: 10.5958/0974-0279.2022.00035.0.

Nimbrayan P K and Bhatia J K 2019. Growth and instability in area, production and productivity of Barley in Haryana vis-à-vis India. *Curr Appl Sci Technol* **1**: 1-8.

Paul K S R, Farukh M and Rambabu V S 2013. Trends, growth and variability of ground nut crop in Andhra Pradesh. *Arts Education* **2:** 74-78.

Saxena R and Chand R 2017. Understanding the recurring onion price shocks: revelations from production-trade-price linkages. Policy Paper No. 33, National Centre for Agricultural Economics and Policy Research, New Delhi. 75p.

Shrestha R B, Huang W C and Ghimire R 2014. Market price cointegration of tomato: effects to Nepalese farmers. *IJFAEC* **2**: 86-87.

Singh N 2017. Comparative Economics of Vegetable Cultivation Under Open and Protected Conditions in Solan district of Himachal Pradesh. M.Sc. Thesis. Department of Social Sciences. Dr. YSP UHF, Nauni, India. 80p.

Singh R and Mishra R 2018. Market integration and price behaviour of tomato in India: An empirical analysis. *Agric Econ Res Rev* **31:** 219-229.

Singh P, Guleria A, Vaidya M K and Sharma S 2020a. Determinants of diversification in relation to farm size and other socio-economic characteristics for sustainable hill farming in Himachal Pradesh. *Indian J Economics Dev* **16:** 418-424. DOI: 10.35716/IJED/20064.

Singh P, Vaidya M K, and Divyanshu 2020b. Marketing efficiency and problems of peach crop in Himachal Pradesh of northwestern Himalayan region. *Int J Farm Sci* **10:** 22-30.

Singh P, Adhale P, Guleria A, Bhoi P B, Bhoi A K, Bacco M and Barsocchi P 2022a. Crop diversification in South Asia: A panel regression approach. *SUSTDE* **14**: 9363. DOI: 10.3390/su14159363.

Singh P, Adhale P, Guleria A and Vaidya M K 2022b. Is crop diversification vulnerable to climate, agricultural and socio-economic factors in Himachal Pradesh, India? *Curr Sci* **123**: 707-11. DOI: 10.18520/cs/v123/i5/707-711.

Singh P, Guleria C and Vaidya M K 2022c. Market integration and price volatility in tea market of India. *Indian J Ecol* **49:** 2364-69. DOI: 10.55362/IJE/2022/3834.