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Price dynamics of soybean in India: An econometric analysis

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Abstract
Soybean (*Glycine max* L.), popularly known as the "golden bean," is a vital oilseed crop that significantly contributes to India's agricultural economy. This study was conducted to analyze the seasonality and market integration of soybean prices in major market of India, including Latur (Maharashtra), Dewas (Madhya Pradesh), Kota (Rajasthan), Bidar (Karnataka), and Junagadh (Gujarat), using data from January 2015 to December 2024. Secondary data on monthly prices and arrivals were collected from APMCs and the AGMARKNET portal. Seasonal indices were calculated using the twelve-month ratio-to-moving-average method to examine price and arrival patterns, while the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were applied to check stationarity. Johansen’s cointegration test and the Granger causality test were used to assess long-run price relationships and causal linkages among markets. The results revealed that soybean arrivals peaked during October-December, while prices were highest in March-May, demonstrating an inverse relationship between supply and price. Stationarity tests indicated that all price series were non-stationary at levels but stationary at first differences I (1). Johansen’s cointegration confirmed strong long-run price integration among markets, particularly Dewas-Bidar, Bidar-Junagadh, and Latur-Bidar, while Granger causality analysis identified both bidirectional and unidirectional price transmissions, with Latur, Kota, and Bidar emerging as price-leading markets. The study highlights the need for understanding seasonality and market linkages to improve marketing strategies, ensure better price realization for farmers, and support policy interventions for market stability.

Keywords: Soybean, seasonality, ADF and PP test, co-integration, Johansen test, granger causality test

Introduction
Soybean (*Glycine max* L.), commonly known as the "golden bean" or "miracle bean" of the 21st century, is a vital oilseed crop that serves as a major source of high-quality protein and oil. Globally, it is cultivated on 136.90 million hectares with a production of 371.17 million metric tonnes, where Brazil, the USA, and Argentina are the leading producers, while India ranks fourth in area and fifth in production, contributing 3-4 percent of global output. In India, soybean is mainly grown in Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, and Gujarat, with Madhya Pradesh and Maharashtra together accounting for more than 80 percent of production. Despite its growing importance and role in driving the "Yellow Revolution," soybean prices remain highly volatile due to factors such as market arrivals, climatic conditions, crop health, carryover stocks, import-export trends, and global demand-supply dynamics. Prices typically decline during the peak harvest season (October-December) and rise during lean months (March-May), reflecting a clear seasonal pattern. In India, soybean markets are interconnected, with price changes in one market influencing others, making the study of seasonality, and market integration crucial for farmers, policymakers, and market participants. Analyzing past price trends helps farmers choose the best time to sell, assists consumers in making timely purchases, and enables the government to implement effective policies such as procurement and buffer stock releases, ultimately improving the marketing system and ensuring fair price realization for farmers. Therefore, the present study has undertaken with following specific objective:

- To know the seasonality in soybean prices in major markets of India.
- To know the market integration among the major soybean markets of India.

Methodology

Data Sources

This study utilizes authoritative secondary data sources to ensure analytical validity. Monthly time-series data on Soybean prices and arrivals were extracted from major Agricultural Produce Market Committees (APMCs) and the AGMARKNET portal. Soybean was selected as the focal crop due to its status as India's largest oilseed in terms of cultivated area, production volume, and contribution to agricultural gross value added. The research is confined to five major producing states Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, and Gujarat and from each, one representative market was chosen based on the triennium average of arrivals: Dewas, Latur, Kota, Bidar, and Junagadh, respectively. The study period spans January 2015 to December 2024.

Analytical Tools

Seasonality Analysis

Monthly data on wholesale prices and market arrivals were utilized to analyze the seasonal patterns in the selected markets. To quantify the seasonal fluctuations in both prices and arrivals, seasonal indices were derived using the twelve-month ratio-to-moving-average technique.

- Step I, involved calculating the 12-month moving totals, which were then divided by 12 to obtain the corresponding moving averages. These moving averages were further refined into a series of centred moving averages. A time span of 10 years of data was used for the computation of seasonal indices.
- Step II converted the original monthly values into percentages relative to their respective centred moving averages. This step also involved eliminating the irregular components from the time series. The resulting percentages were then grouped by month, and average values for each month were computed.
- Step III included adjusting the monthly average indices so that their total equalled 1200. This can be done by working out a correction factor and multiplying the average for each month by this correction factor.

The correction factor (K) is worked out as follows,

$$K = 1200/S$$

Where, K is a correction factor
S is the sum of average indices for 12 months
Multiply K with the percentage of moving average for each month to obtain the seasonal indices.

Market co-integration

Testing of stationarity in price series.

To address the issue of spurious regression that could result from non-stationarity, this study initially tested the stationarity of the time series data using the Augmented Dickey-Fuller (ADF) test. Before investigating any long-term equilibrium relationships among price series through co-integration techniques, it was necessary to confirm that the data were stationary. This step served a*et al*s the foundation for all subsequent time series analyses. The ADF unit root test, developed by Dickey and Fuller (1979) [3], was employed to identify whether a unit root existed in the data. The presence of a unit root at level form indicated non-stationarity. In such cases, the series was differenced once, and the ADF test was reapplied to assess whether the differenced series had achieved stationarity. The ADF test is estimated using the following regression equation:

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

$$\Delta P_t = P_t - P_{t-1},\ \Delta P_{t-1} = P_{t-1} - P_{t-2} \ldots\ldots\ldots.\ \Delta P_{n-1} = P_{n-1} - P_{n-2}$$

Where,
P = Prices in each market
α_0 = Constant term or drift
q = The value of lags
ε_t = White noise error term

The values for this test statistic are compared with the dickey fuller values.
The null and alternate hypothesis tested in ADF are

- **(H0):** β1 (Coefficient of Pt-1) is zero.
- **(H1):** β1 < 0

The null hypothesis in this context stated that the time series contained a unit root, indicating non-stationarity. In contrast, the alternative hypothesis asserted that no unit root was present, implying that the series was stationary.
Similar to the ADF test, PP test indicated the presence of a unit root at the level form, it suggested that the time series was non-stationary. In such cases, the series was transformed through first differencing, and the test was re-applied to the differenced series to determine stationarity.

Co-integration analysis using Johanson procedure

The Johansen cointegration test is a widely used statistical method for evaluating the existence and strength of long-term equilibrium relationships among non-stationary time series variables. This approach is applicable only when the time series are integrated of the same order, typically stationary at first difference. The Johansen framework includes two key techniques for determining cointegration: the Trace test and the Maximum Eigen value test. (Johansen, 1988; Johansen and Juselius, 1990) [4, 5]
The model with n variable vectors was given as,

$$x_t = A_1 x_{t-1} + \varepsilon_1$$

So that,

$$\Delta x_t = A_1 x_{t-1} - x_{t-1} + \varepsilon_1$$
$$= \prod x_{t-1} + \varepsilon_1$$

Where,
x_t, ε_t are (n×1) vectors,
A_1 is (n×n) matrix of parameter,
I is (n×n) identity matrix
We test the rank of A_1-I matrix i.e., $\prod = A_1 - I$. If the rank is Π=k, then the series is stationary in nature. If the rank is $\Pi<k$, also known as reduced rank, then there exists cointegration among the series

Granger Causality Test

The presence and causality direction of long-run market price relationship can be assessed by using the Granger causality test directed within vector auto regressive (VAR) model. To perform the Granger causality analysis, an

Autoregressive Distributed Lag (ADL) model was specified as follows:

$$X_0 = \sum_{i=1}^{n} \alpha_i Y_{0-i} + \sum_{i=1}^{n} \beta_i X_{0-j} + u_1$$

$$Y_0 = \sum_{i=1}^{n} \lambda_i Y_{0-i} + \sum_{i=1}^{n} \delta_i X_{0-j} + u_2$$

Where,
µ1 & µ2 are error terms
t = time period
X_0 & Y_0 are the price series of two different markets
To test the pattern of causality between two markets, 'F' test was used.

The null hypothesis

- **H0:** The lagged X_0 does not granger cause Y_0 The Alternative hypothesis
- **H1:** The lagged X_0 granger cause Y_0

Here 'F' statistic must be used in combination with the p value when deciding about the significance of the results.
If 'p' value is less than the alpha level, individual p values are studied to find out which of the individual variables are statistically significant.

Results and Discussion

Seasonal indices of market arrivals of soybean in major markets of India.

Seasonal indices for arrivals have been estimated using the 12-month moving averages to determine the long-term seasonal variations of soybean arrivals in the specified major markets. The results provide insights into cyclical patterns influenced by harvesting schedules and market behaviour. The seasonal indices of monthly market arrivals of soybean in the major markets are presented in Table 1. In Latur, the highest arrivals were observed in November (233.20), followed by December (183.30) and January (130.50), while the lowest occurred in July (34.50), indicating limited supply during the monsoon season. Dewas showed a similar trend, with peaks in October (193.60), November (184.80), and December (156.30), and the lowest in March (53.50) and April (61.40). In Kota, arrivals were highest in October (349.30), followed by November (205.20) and December (117.10), with the leanest months being May (36.50) and April (42.80) reflecting the off-season. Bidar exhibited the sharpest seasonal contrast, recording peak arrivals in October (404.50) and November (309.80), and the lowest in August (12.30) and July (14.10). Similarly, Junagadh recorded its highest indices in October (354.10), November (318.90), and December (165.20), with minimal arrivals in July (17.80) and August (17.60). These results reflect a strong seasonality across markets, with arrivals concentrated during the post-harvest months (October to December) and minimal activity during the monsoon season (July-August), aligning More and Katkade (2016) [7], who reported peak soybean arrivals in October to December and minimal inflows during July to September in the Marathwada region. Saha *et al.* (2020) [13], who also reported higher arrivals during the peak harvest season and lower inflows during the monsoon months, indicating a clear seasonal pattern in agricultural markets.
The seasonal indices of all markets displayed in Figure 1 shows that arrivals peak from October to November in all markets, while the lean season is typically during July to September, reflect the influence of harvesting patterns, climatic conditions, and supply chain dynamics associated with soybean cultivation in India.

Seasonal indices of market prices of soybean in major markets of India.

The seasonal indices of monthly market prices of soybean in selected markets are presented in Table 2. The monthly market price results revealed that in the Latur market, the highest price index was observed in April at 106.20, while the lowest price index was found in October at 92.40. In the Dewas market, the highest price index was in May at 105.00, followed by April (104.90) and June (104.40), while the lowest price index was recorded in October at 93.10. In the Kota market, the highest price index was in April at 106.40, followed by May (106.20), while the lowest price index was recorded in October at 90.60. In the Bidar market, the highest price index was in April at 108.60, while the lowest price index was found in October at 86.60. In the Junagadh market, the highest price index was in April at 106.30, followed by May (103.30), while the lowest price indices were observed in August (97.60)

Table 1: Seasonality in soybean Arrivals in Major Markets of India.

Month/Market	Latur (MH)	Dewas (MP)	Kota (RJ)	Bidar (KA)	Junagadh (GJ)
Jan	130.50	119.70	76.30	110.50	118.30
Feb	99.80	85.90	64.10	64.90	59.20
Mar	75.40	53.50	62.50	35.50	29.10
Apr	85.60	61.40	42.80	35.10	33.20
May	83.00	50.70	36.50	17.80	34.70
Jun	67.50	70.00	67.30	24.70	26.80
Jul	34.50	87.30	85.70	14.10	17.80
Aug	36.50	63.00	51.50	12.30	17.60
Sep	42.60	73.80	47.80	30.60	25.00
Oct	128.10	193.60	349.30	404.50	354.10
Nov	233.20	184.80	205.20	309.80	318.90
Dec	183.30	156.30	111.10	140.20	165.20

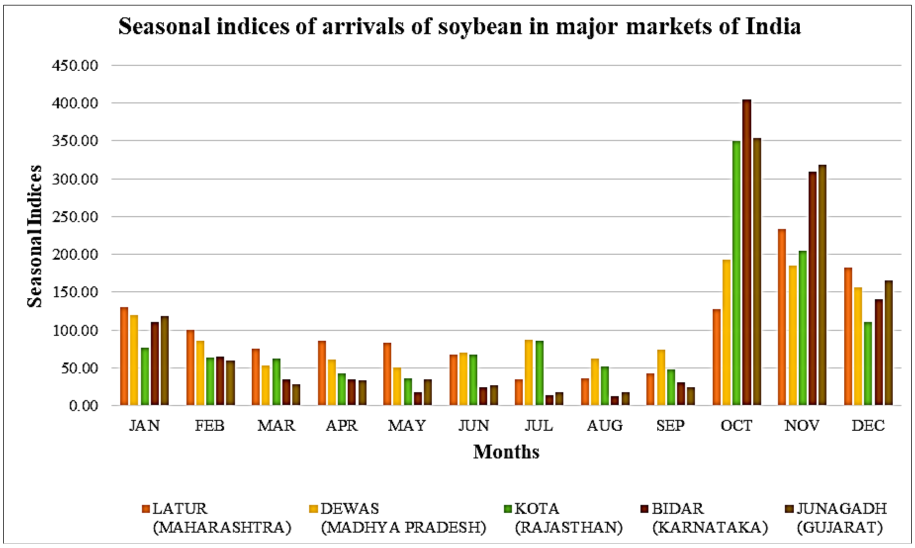

Fig 1: Seasonal indices of market arrivals of soybean in major markets of India.

and July (98.20). All the markets experienced higher prices during the off-season (April-May), while prices tended to be lowest price indices were observed mostly during October to November, aligning with the post-*Kharif* arrival season when market supply increases sharply. Bodade *et al.* (2017) [2] reported that soybean prices in Madhya Pradesh peaked in May and declined during September to November due to increased post-harvest arrivals. Similarly, Walke *et al.* (2020) [14] observed that soybean prices in Maharashtra were highest in May and lowest in October, confirming the seasonal nature of price fluctuations.

Table 2: Seasonality in soybean prices in major markets of India**.**

Month/Market	Latur (MH)	Dewas (MP)	Kota (RJ)	Bidar (KA)	Junagadh (GJ)
Jan	99.10	97.90	99.00	101.30	102.00
Feb	100.70	101.60	100.80	101.20	103.50
Mar	102.00	100.50	101.70	102.80	101.20
Apr	106.20	104.90	106.40	108.60	106.30
May	104.30	105.00	106.20	105.10	103.30
Jun	102.10	104.40	102.80	101.80	100.90
Jul	100.90	100.50	100.70	102.70	98.20
Aug	99.90	99.80	99.90	101.00	97.60
Sep	99.10	101.00	97.40	93.80	93.00
Oct	92.40	93.10	90.60	86.60	93.30
Nov	95.80	95.20	96.90	95.00	99.10
Dec	97.40	96.30	97.60	100.10	101.50

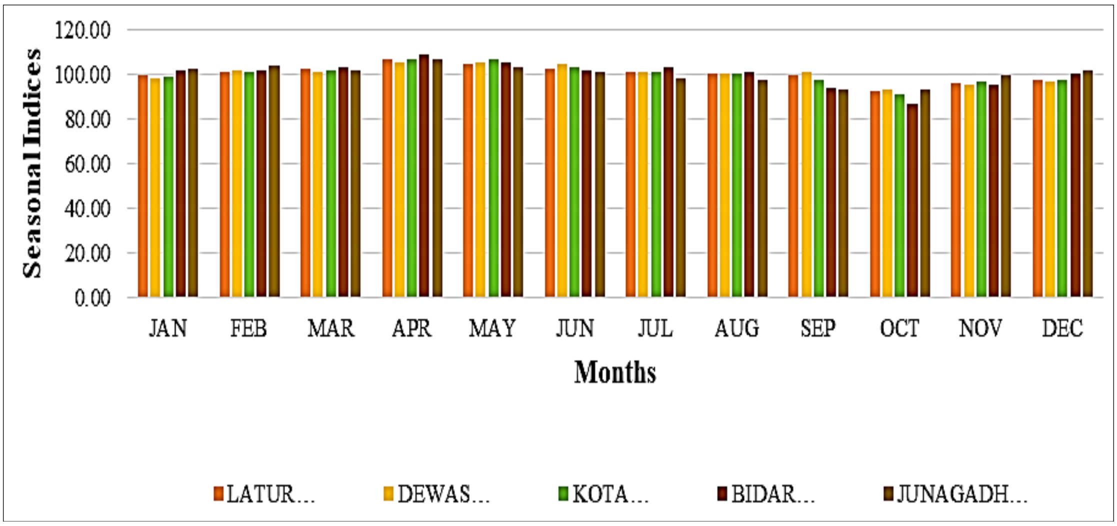

Fig 2: Seasonal indices of market prices of soybean in major markets of India.

The seasonal indices of all markets displayed in Figure 2 shows that prices were generally highest from March to May and declined from September to November, indicating an inverse relationship between price and arrival trends across markets

Augumented Dickey- Fuller (ADF) test

The Augmented Dickey-Fuller (ADF) test, a standard method for detecting unit roots, was employed to statistically verify the stationarity of Soybean prices in these major markets for Johansen co-integration analysis, and the results are summarized in Table 3.

Table 3: Estimates of Augmented Dickey-Fuller Test for stationarity and order of integration

Markets	At Level Data			First Differenced Data		
	None	Intercept	Trend and Intercept	None	Intercept	Trend and Intercept
APMC-Latur						
't' -Statistics	0.2630	-1.7351	-1.5599	-8.4390	-8.4078	-8.4024
Probability Value	0.7605	0.5121	0.8021	0.0000	0.0000	0.0000
Schwarz Criterion Value	-2.2673	-2.2463	-2.2065	-2.3109	-2.2676	-2.2268
APMC-Dewas						
't' -Statistics	0.2338	-1.6792	-1.8587	-10.5504	-10.5100	-10.4985
Probability Value	0.7522	0.4388	0.6688	0.0000	0.0000	0.0000
Schwarz Criterion Value	-2.3186	-2.3017	-2.2673	-2.3100	-2.2670	-2.2270
APMC-Kota						
't' -Statistics	0.2272	-1.6111	-1.8092	-8.9968	-8.9611	-8.9374
Probability Value	0.7503	0.4734	0.6935	0.0000	0.0000	0.0000
Schwarz Criterion Value	-2.1657	-2.1467	-2.1114	-2.1733	-2.1300	-2.0880
APMC-Bidar						
't' -Statistics	0.1691	-1.8774	-2.2028	-8.8676	-8.8323	-8.8184
Probability Value	0.7333	0.3418	0.4829	0.0000	0.0000	0.0000
Schwarz Criterion Value	-1.8100	-1.7997	-1.7702	-1.8219	-1.7784	-1.7370
APMC-Junagadh						
't' -Statistics	0.3004	-1.4624	-1.6611	-8.5481	-8.5201	-8.5062
Probability Value	0.7709	0.5488	0.7616	0.0000	0.0000	0.0000
Schwarz Criterion Value	-2.4309	-2.4077	-2.3721	-2.4597	-2.4169	-2.3758

The ADF test showed that the price series for all five markets-APMC-Latur, APMC-Dewas, APMC-Kota, APMC-Bidar, and APMC-Junagadh were non-stationary at the level form across all model specifications (None, Intercept, and Trend and Intercept), as the test statistics did not exceed the corresponding critical values. High p-values further indicated the failure to reject the null hypothesis of a unit root. However, when tested in their first-differenced forms, the test statistics for all markets were highly significant under every specification, with p-values of 0.0000 in each case. The ADF values were more negative than the critical values at both the 5% and 1% significance levels, leading to the rejection of the null hypothesis. This confirms that the Soybean price series became stationary after first differencing in each market.

To ensure the robustness and conformity of the stationarity results, the Phillips-Perron (PP) test, an alternative unit root testing procedure, was also conducted alongside the Augmented Dickey-Fuller (ADF) test. The results reinforced the conclusion that while soybean prices in the selected markets exhibit non-stationarity in their level forms, they become stationary after first differencing. Such conformity between the two testing procedures strengthens the reliability of the results and suggests that the soybean price series follow an integrated order of I (1). The present study findings suggest that soybean price series are non-stationary at levels but stationary after first differencing aligning with More *et al.* (2015) [8] study on sorghum in Maharashtra, Bharadwaj *et al.* (2015) [1] on future trading in soybean in India and Kumari *et al.* (2021) [6] in their analysis of wholesale Soybean prices in India, where ADF results showed non-stationarity at level and stationarity at first difference.

Vector Autoregressive Model

A crucial step in estimating the Vector Autoregressive (VAR) model is selecting an appropriate lag length, as the model's accuracy and stability depend on it. Common criteria such as the Akaike Information Criterion (AIC), Final Prediction Error (FPE), Likelihood Ratio (LR) test, Bayesian Information Criterion (BIC), and Hannan-Quinn Criterion (HQC) help balance explanatory power with the risk of overfitting. Based on these criteria, particularly AIC, FPE, and LR, the optimal lag length was determined to be 2. Using this lag structure, the Johansen cointegration test (Table 5) confirmed the presence of cointegration among soybean markets, indicating a long-run price association. A similar approach was adopted by Rani *et al.* (2017) [12].

Cointegration among the markets

Cointegration analysis revealed strong long-run price linkages among several soybean market pairs, notably Dewas-Bidar, Bidar-Junagadh, and Latur-Bidar, where both trace and Max-Eigen statistics significantly exceeded the 5% critical values with p-values below 0.05 showed in Table 4. Moderate cointegration was also observed for Dewas-Junagadh, Kota-Bidar, Latur-Junagadh, and Kota-Junagadh, while pairs like Latur-Dewas and Dewas-Kota showed weaker alignment. Overall, these results confirm that most soybean markets in the study region are well-integrated, with prices moving together in the long run, although the strength of integration varies across market pairs. Tingre *et al.* (2016) applied Johansen's multiple cointegration test across major soybean markets in India, including Latur, Akola, Kota, Bailhongal, and Nizamabad, and established strong long-run price associations. Similarly, Paul (2014) [9], Praveen and Inbasekar (2015) [11], and Paul also reported the existence of long-run equilibrium relationships and cointegration among various agricultural markets in India

Table 4: Johansen's Cointegration test results for soybean major market of India

Markets	Hypothesized No. of CS	Trace Statistics	Critical Value at 5%	Probability Value	Max Eigen Statistics	Critical Value at 5%	Probability Value	Lag Length (AIC)
Latur -Dewas	None	15.63	15.49	0.0477	13.60	14.26	0.0635	5
	At most 1	2.04	3.84	0.1537	2.04	3.84	0.1537	
Latur -Kota	None	24.15	15.49	0.0020	20.84	14.26	0.0040	2
	At most 1	3.30	3.84	0.0692	3.30	3.84	0.0692	
Latur -Bidar	None	31.83	15.49	0.0001	28.02	14.26	0.0002	2
	At most 1	3.81	3.84	0.0509	3.81	3.84	0.0509	
Latur - Junagadh	None	24.47	15.49	0.0017	21.34	14.26	0.0032	2
	At most 1	3.13	3.84	0.0769	3.13	3.84	0.0769	
Dewas -Kota	None	18.77	15.49	0.0155	16.71	14.26	0.0200	5
	At most 1	2.05	3.84	0.1526	2.05	3.84	0.1526	
Dewas -Bider	None	36.73	15.49	0.0000	33.67	14.26	0.0000	2
	At most 1	3.05	3.84	0.0806	3.05	3.84	0.0806	
Dewas - Junagadh	None	29.81	15.49	0.0002	26.98	14.26	0.0003	1
	At most 1	2.83	3.84	0.0927	2.83	3.84	0.0927	
Kota- Bider	None	29.87	15.49	0.0002	26.52	14.26	0.0004	2
	At most 1	3.35	3.84	0.0672	3.35	3.84	0.0672	
Kota- Junagadh	None	25.68	15.49	0.0011	22.89	14.26	0.0170	2
	At most 1	2.79	3.84	0.0947	2.79	3.84	0.0947	
Bidar- Junagadh	None	35.97	15.49	0.0000	32.53	14.26	0.0000	1
	At most 1	3.44	3.84	0.0635	3.44	3.84	0.0635	

Granger Causality test

The Granger causality test (Table 5) revealed strong price interdependencies among soybean markets in Latur, Dewas, Kota, Bidar, and Junagadh. Bidirectional causality was observed in key pairs such as Latur-Dewas, Latur-Kota, Latur-Bidar, Dewas-Bidar, and Kota-Bidar, indicating robust price integration. Several unidirectional linkages were also identified, including Dewas → Latur, Kota → Dewas, Bidar → Dewas, and Junagadh → Kota and Bidar, highlighting the price leadership roles of Latur, Kota, and Bidar. In contrast, no significant causality was found in pairs like Latur-Junagadh or Dewas-Kota, aligning with Kumari *et al.* (2021) [6] and Bodade *et al.* (2017) [2], who also reported both bidirectional and unidirectional price transmissions among major soybean markets.

Table 5: Pair -wise granger causality of soybean prices in major market of India.

Markets	F-Statistics	Probability Value	Granger Cause	Direction
Latur-Dewas	17.36	0.0001	Yes	Bidirectional
Dewas-Latur	3.90	0.0234	Yes	
Latur-Kota	22.49	0.0001	Yes	Bidirectional
Kota-Latur	5.01	0.0085	Yes	
Latur-Bidar	4.55	0.0128	Yes	Bidirectional
Bidar-Latur	3.53	0.0331	Yes	
Latur-Junagadh	0.33	0.7219	No	Unidirectional
Junagadh-Latur	7.03	0.0014	Yes	
Dewas-Kota	2.53	0.0845	No	Unidirectional
Kota-Dewas	4.00	0.0212	Yes	
Dewas-Bidar	7.84	0.0007	Yes	Bidirectional
Bidar-Dewas	21.29	0.0001	Yes	
Dewas-Junagadh	1.85	0.1619	No	Unidirectional
Junagadh-Dewas	13.88	0.0001	Yes	
Kota-Bidar	4.46	0.014	Yes	Bidirectional
Bidar-Kota	15.38	0.0001	Yes	
Kota-Junagadh	2.94	0.572	No	Unidirectional
Junagadh-Kota	16.85	0.0001	Yes	
Bidar-Junagadh	1.21	0.3039	No	Unidirectional
Junagadh-Bidar	17.71	0.0001	Yes	

Conclusion

The study revealed clear seasonal patterns in soybean arrivals and prices, with arrivals peaking during October-December and prices reaching their highest levels from March to May, reflecting the inverse relationship between supply and price. Stationarity tests (ADF and PP) confirmed that price series are non-stationary at levels but become stationary after first differencing, indicating an integrated order of I (1). The Johansen cointegration test demonstrated strong long-run price linkages among key market pairs such as Dewas-Bidar, Bidar-Junagadh, and Latur-Bidar, while moderate integration was observed in other pairs. Granger causality analysis further identified bidirectional price transmission among major markets, along with unidirectional influences that highlight the price leadership roles of Latur, Kota, and Bidar. These findings confirm that soybean markets in India are well-integrated, with prices moving together over the long run, although the strength of integration varies across regions.

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