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Manjanagouda I Patil
M.Sc. (Agricultural) Student, Department of Agricultural Economics, College of Agriculture, VNMKV, Parbhani, Maharashtra, India

Sachin S More
Head, Department of Agricultural Economics, College of Agriculture, VNMKV, Parbhani, Maharashtra, India

Vasant G Jadhav
Ph.D. Research Scholar, Department of Agricultural Economics, College of Agriculture, VNMKV, Parbhani, Maharashtra, India

Corresponding Author:
Manjanagouda I Patil
M.Sc. (Agricultural) Student, Department of Agricultural Economics, College of Agriculture, VNMKV, Parbhani, Maharashtra, India

Market integration and price forecasting of pigeon pea in major markets of Maharashtra

Manjanagouda I Patil, Sachin S More and Vasant G Jadhav

Abstract
India is the largest pulse-producing country in the world. In India major pigeon pea-cultivated states are Maharashtra, Karnataka, Telangana, Andhra Pradesh, Uttar Pradesh, and Gujarat. In that Maharashtra rank first in pigeon pea production at national level. The present study aimed to know Market integration and forecasting of Pigeon pea prices in major markets of Maharashtra. For study purpose the monthly time series data of the pigeon pea crop of Nanded, Yavatmal, Latur, Amaravati, and Buldhana APMC markets were collected from official records for last thirteen years i.e. 2011 to 2023. The data were analyzed with the help of statistical tools viz., Johansen cointegration test and Box Jenkins method of price forecasting especially the SARIMA model. The results of the co-integration test showed that there exists a long-run equilibrium relation in the Pigeon pea markets. The forecast of Pigeon pea prices for the Latur market in Maharashtra for the year 2024 shows that the short-run price forecast of pigeon pea exhibits an uptrend.

Keywords: Pigeon pea**,** market integration, Johansen test, price forecast, SARIMA model

Introduction
In India, major pulses like chickpea, pigeon pea, green gram, black gram, lentils, and peas are typically grown under rainfed conditions, making them ideal for areas where water-intensive crops are not prioritized. But this study focuses on pigeon pea as it is the second most important pulse in Maharashtra, after chickpea, and holds significant economic value for farmers. Pigeon pea, a major pulse crop native to India, is now widely grown in tropical and subtropical regions around the world. With approximately 22% protein, three times more than cereals, it is a nutritious and affordable staple, widely consumed as "Dal" by vegetarians.

The global pulse production stands at approximately 973.92 lakh tonnes, with India leading in both area and production. (FAOSTAT, 2022) [3]. India contributes 361.11 lakh hectares of cultivated land and produces 276.69 lakh tonnes of pulses annually. The top five pulse-producing states in India are Rajasthan, Madhya Pradesh, Maharashtra, Uttar Pradesh, and Karnataka. (Anonymous 2022) [1]

The major pigeon pea producing countries in the world include India, Malawi, Myanmar, Tanzania, and Kenya. Global pigeon pea production stands at approximately 53.27 lakh tonnes, with India being the dominant producer. India together with Malawi and Myanmar are some of the major leading countries producing 7.74 lakh tonnes of pigeon pea globally. In India, during 2021-2022, area of pigeon pea cultivation was 49.00 lakh ha with production of 42.20 lakh tonnes (FAOSTAT, 2022) [3]. The area and production of Pigeon pea in Maharashtra during 2021-22 was 1335.10 thousand ha with an annual production of 1391.17 thousand tonnes (INDIASTAT, 2021-22) [2].

Objectives
1. To study co-integration among major Pigeon pea markets in Maharashtra
2. To Forecast prices of pigeon pea in Latur market of Maharashtra

Analyzing market integration enables one to assess how closely prices fluctuate among various markets, hence revealing the stability and efficiency of the market. In order to guarantee that farmers get fair pricing for their goods, this understanding is crucial. Based on market integration, short-term price forecasting gives farmers insightful information about future price

trends, which helps them make better decisions about selling their commodities. Therefore the present study has been taken.

Methodology

For study purpose the major pigeon pea markets from the Maharashtra State were selected viz., Latur, Nanded, Buldhana, Amaravati, and Yavatmal. As per the records available, the time series data on monthly average prices of pigeon pea for the period from 2011 to 2023 was collected from the Agmarknet website.

Testing of stationarity in the Pigeon pea price series

Before analyzing any time series data testing for stationarity is a prerequisite. The stationarity of time series data on pigeon pea prices was tested by applying the Augmented Dickey-Fuller test (ADF). The (ADF) test is the test for the unit root in a time series sample. A stationary series is one whose parameters are independent of time, exhibiting constant mean and variance and having autocorrelations that are invariant through time. If the series is found to be non-stationary, the first-order differences of the series are tested for stationarity. The number of times (d) a series is differenced to make it stationary is referred to as the order of integration, I(d).

ADF unit root test are based on the following three regression forms:

Without constant and trend $\Delta Yt = \delta Yt\text{-}1 + ut$

With constant $\Delta Yt = \alpha + \beta T + \Delta Yt\text{-}1 + ut$

With constant and trend

Testing of Co-integration between Pigeon pea prices of selected markets

To check whether selected markets are cointegrated. The most common methods used are the Engle-Granger two-step method and the Johansen cointegration test. The Engle-Granger test is simpler, involving a single linear regression followed by a unit root test on residuals. However, it is limited to testing cointegration between only two variables. The Johansen cointegration test, on the other hand, can handle multiple variables simultaneously, making it more robust for analyzing systems with more than two markets. So, In our study the Johansen test is used because of its ability to identify multiple cointegrating relationships while considering all variables as endogenous. This makes it ideal for complex financial systems where markets influence each other. By analysing interactions among multiple variables simultaneously, the test provides deeper insights into long-run equilibrium relationships, offering a comprehensive understanding of how different markets move together over time.

The monthly modal price data of pigeon pea was gathered over a 13-year period (From January 2011 to December 2023) for selected markets in Maharashtra. Based on the volume of arrivals, the Latur market was identified as the most suitable for forecasting pigeon pea prices. The study utilized the ARIMA model, which predicts values by analyzing equally spaced unilabiate time series data through a linear combination of past values, incorporating seasonal effects due to significant seasonal price fluctuations. Consequently, the Box-Jenkins methodology of the Seasonal ARIMA (SARIMA) model was applied, combining both non-seasonal and seasonal factors in a multiplicative model.

A shorthand notification for the model in ARIMA (p, d, q) x (P, D, Q)s

With

p= non seasonal AR order,

d= non seasonal differencing,

q= non seasonal MA order,

P= seasonal AR order,

D= seasonal differencing,

Q= seasonal MA order, and

s= time span of repeating seasonal pattern.

Results and Discussion

Testing of stationarity in the Pigeon pea price series

The stationarity in time series data of pigeon pea was tested by applying the Augmented Dickey-Fuller (ADF) test. The Augmented Dick-Fuller (ADF) test was applied for price data of major markets of Pigeon pea in Maharashtra i.e. Nanded, Yavatmal, Latur, Amaravati, and Buldhana markets and the results are presented in Table 1.

From Table 1 it was observed that at level, the ADF values were more than critical values at 1 percent level of significance indicating the existence of unit root implied that the prices series in all markets were non-stationary. The table further showed that at 1st order difference, the ADF values were lower than the critical values at 1 percent level of significance indicating that the price series were free from the consequences of unit root. This implied that the price series were stationary at 1st order difference. Ghosh (2011) [4] found that the prices of rice and wheat were non-stationary at levels but became stationary in first differences implying that all the series of rice and wheat prices contain a single unit root and are integrated at order one.

Market Co-integration between Pigeon pea prices of selected markets

From Table 2 it was observed that the presence of at least three co-integration equations at 5 per cent level of significance confirms that there exists a long-run equilibrium relation in the prices of pigeon pea in selected markets. The results of Co-integration test showed three co-integration equations were significant at 5% level of significance which implied that there existed cointegration among the markets. Horo *et al.* (2019) [5] reported that three co-integrating equations were found, indicating significant long-term equilibrium relationships among pigeon pea markets in the seven major pigeon-pea-producing states of India.

Identification of the model was concerned with deciding the appropriate values of (p, d, q) (P, D, Q). It was done by observing Auto Correlation Function (ACF) and Partial Auto Correlation Function (PACF) values. The Auto Correlation Function helps in choosing the appropriate values for ordering of moving average terms (MA) and Partial Auto-Correlation Function for those autoregressive terms (AR). The number of non-zero coefficients in ACF determines order of MA terms and the number of non-zero coefficients in PACF plots determines order of AR terms.

Based on the lowest values of AIC, Normalized BIC and Hannan-Quinn criteria best model for pigeon pea price forecasting in the Latur APMC market was identified. Table 3 reveals that SARIMA (1, 1, 0) $(0, 1, 2)_{12}$ model for pigeon pea price was found to be the most appropriate model among the 20 competitive models tested for the Latur APMC market with the least AIC (-2.548), BIC (-2.450), and Hannan-Quinn (-2.509) values.

The estimate of the identified model for pigeon pea price forecasting using SARIMA (1,1,0) $(0,1,2)_{12}$ was presented in Table 4. The estimate of AR and MA seasonal component

was 0.184 and significant. The seasonal MA component of the model were 0.985 and -0.009 for first and second lag respectively. Thombare (2020) also fitted SARIMA model to the maize price data and estimated the parameter for price forecasting using a non-linear estimation procedure.

The ex-ante forecast was conducted and compared with the actual observed values. The ex-ante and ex-post forecasts of pigeon pea prices from January 2011 to December 2023 and the Ex-post forecast of one year ahead for the period January 2024 to December 2024 are displayed in Figure 1 for the Latur APMC market, using the SARIMA model $(1,1,0)(0,1,2)_{12}$. Results revealed that, the price fluctuation in that period Shows similar pattern of price behavior throughout study period hence the fitted model was most suitable.

In Table 5, the pigeon pea price in the Latur market was forecasted to Rs. 9,595 per quintal (Upper limit Rs. 11,039–Lower limit Rs. 8,297) in January 2024, and in December 2024, the forecasted pigeon pea price was Rs 10,958 per quintal (Upper limit Rs. 18,975–Lower limit Rs. 5,781). The prices continued to increase steadily from January to August 2024 and reached a peak in October at Rs. 11,074. Afterwards from November month Prices slightly decrease to Rs. 10,903. The prices in the month of July, August and September, October were Rs. 10,481, Rs. 10,916, Rs. 10,968, Rs. 11,074 showing highest prices because the arrival of pigeon pea in the market was less as compared to peak period of arrival immediate after harvest.

The ACF and PACF plot from the fitted model are displayed in Figure 2. The graph shows that all correlation coefficients remain within the 95 percent confidence bounds, indicating no significant autocorrelation beyond the acceptable range. Since none of the residual autocorrelations exceed the approximate two standard error limits, there is no evidence of a poor fit. These findings suggest that the seasonal ARIMA model $(1, 1, 0)(0, 1, 2)_{12}$ is a suitable model for the data.

Table 1: ADF test results of Pigeon pea prices in major markets of Maharashtra

At level series			
Markets	**Equation I**	**Equation II**	**Equation III**
Nanded	0.82	-1.08	-2.30
Yavatmal	-0.25	-1.95	-2.52
Latur	0.54	-0.97	-1.45
Amaravati	0.05	-1.50	-2.47
Buldhana	0.84	-0.22	-1.24
At 1st Difference series			
Nanded	-14.67	-14.75	-14.73
Yavatmal	-11.59	-11.55	-11.49
Latur	-10.75	-10.76	-10.75
Amaravati	-10.74	-10.71	-10.76
Buldhana	-11.46	-11.51	-11.56
Critical value at 1%	-2.58	-3.47	-4.01

Note: Equation I- None, Equation II- No intercept No trend, Equation III- Intercept and trend

Table 2: Results of Johansen co-integration test

Equation Tested	Hypothesized No. of CE(s)	Trace statistics	critical value @ 5% level	Max-Eigen statistic	critical value @ 5% level
Nanded, Yavatmal, Latur, Amaravati, Buldhana	None *	123.6823	88.80380	43.17756	38.33101
	At most 1 *	80.50478	63.87610	36.00344	32.11832
	At most 2 *	44.50133	42.91525	30.61007	25.82321
	At most 3	13.89126	25.87211	10.71344	19.38704
	At most 4	3.177816	12.51798	3.177816	12.51798

Note: Trace test indicates that 3 co-integrating equations significant at the 5 percent level of significance (* indicates co-integrating equations)

Table 3: Identification of the best-fitted model for the Pigeon pea in Latur market.

Sr. No.	(p, d, q) (P, D, Q)	H.Q	AIC	BIC
1	(1,1,0) (0,1,2)	-2.509	-2.548	-2.450

Table 4: Estimate of fitted SARIMA $(1, 1, 0)(0, 1, 2)_{12}$ model for pigeon pea price series.

Parameter		Estimate	SE	't'	'P'- value
Constant		0.000	0.002	0.261	0.795
AR	Lag 1	0.184	0.085	2.178	0.031
Difference		1			
Seasonal Difference		1			
MA, Seasonal	Lag 1	0.985	0.938	1.050	0.296
	Lag 2	-0.009	0.109	-0.084	0.933

Table 5: Forecasted Pigeon pea prices in Latur market in Maharashtra.

Sr. No.	Month	Forecast	UCL	LCL
1	Jan- 2024	9,595	11,039	8,297
2	Feb-2024	9,872	12,237	7,866
3	Mar-2024	9,996	13,106	7,472
4	Apr-2024	10,181	13,974	7,213
5	May-2024	10,190	14,548	6,887
6	Jun-2024	10,264	15,173	6,647
7	Jul-2024	10,481	15,990	6,527
8	Aug-2024	10,916	17,142	6,552
9	Sep-2024	10,968	17,690	6,359
10	Oct-2024	11,074	18,316	6,214
11	Nov-2024	10,903	18,463	5,928
12	Dec-2024	10,958	18,975	5,781

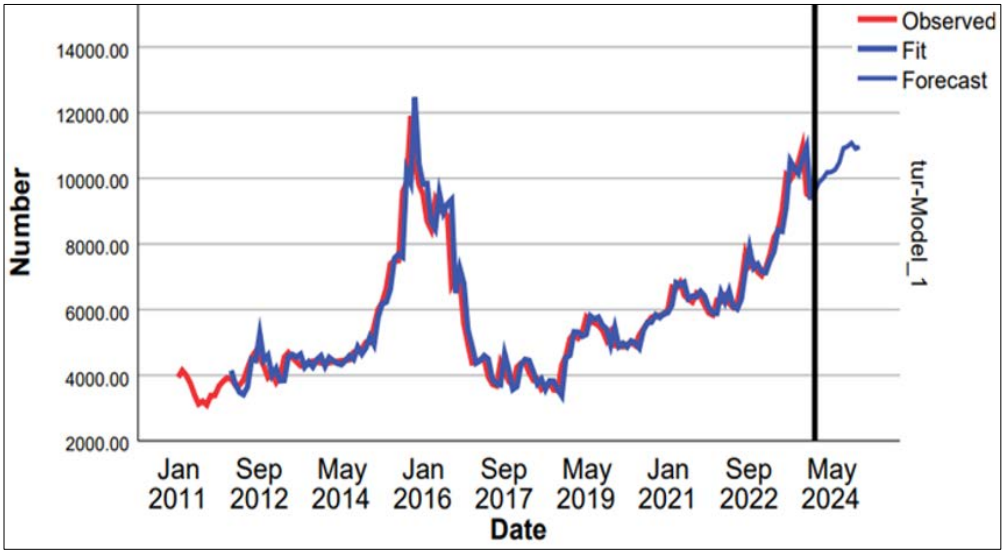

Fig 1: Observed, fitted and forecasted monthly pigeon pea prices in Latur APMC market using SARIMA model (1, 1, 0) $(0, 1, 2)_{12}$

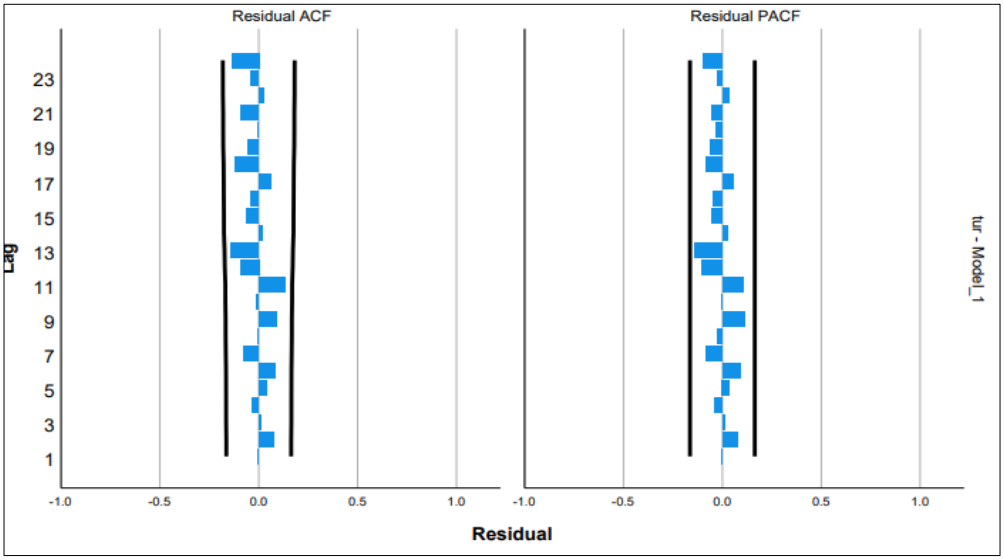

Fig 2: Residual ACF and PACF of fitted ARIMA model (1, 1, 0) $(0, 1, 2)_{12}$ to monthly Pigeon pea price series in Latur APMC market

Conclusion

The following conclusions were emerged from the present study. The price of pigeon pea are stationary at 1st difference level and non-stationary at level. The selected markets have a long-run equilibrium relationship for the prices of pigeon pea and there existed co-integration. The application of SARIMA model (1, 1, 0) $(0, 1, 2)_{12}$ at APMC Latur was most representative model for price forecasting pigeon pea which will be helpful to farmers to make appropriate decisions about storage and sales.

Future Scope

The study of pigeon pea prices offers numerous avenues for exploration, each shedding light on different aspects of market dynamics. Market integration analysis, for instance, reveals the degree of connection between various pigeon pea markets (regional, national, and international), evaluating the

efficiency of price transmission across these markets. on the other hand, price forecasting plays a critical role in predicting future prices, supporting farmers, traders, and policymakers in making informed decisions. The outcomes of this study hold practical value for farmers in making informed decisions and planning their cultivation and sales timelines effectively. They provide insights into the relationship between pigeon pea markets and price fluctuations, aiding planners in devising appropriate export and import policies for pulses. This study helps us to study the extent to which price changes in one market affect the prices of the other market

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