International Journal of Research in Agronomy 2025; SP-8(1): 475-479

International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2025; SP-8(1): 475-479
Received: 06-12-2024
Accepted: 12-01-2025

Dipti
PG Scholar, Department of Agricultural Statistics and Social Science (L.), IGKV, Raipur, Chhattisgarh, India

D Nishad
Assistant Professor, Pt. SKS College of Agriculture and Research Station, Surgi, Rajnandgaon, Chhattisgarh, India

D Prasad
Assistant Professor, Pt. SKS College of Agriculture and Research Station, Surgi, Rajnandgaon, Chhattisgarh, India

MK Deshmukh
Assistant Professor, Pt. SKS College of Agriculture and Research Station, Surgi, Rajnandgaon, Chhattisgarh, India

Reshma Rakse
PG Scholar, Department of Agricultural Statistics and Social Science (L.), IGKV, Raipur, Chhattisgarh, India

Sandeep Sonkar
PG Scholar, Department of Agricultural Statistics and Social Science (L.), IGKV, Raipur, Chhattisgarh, India

Corresponding Author:
Dipti
PG Scholar, Department of Agricultural Statistics and Social Science (L.), IGKV, Raipur, Chhattisgarh, India

Evaluation of statistical models for forecasting of area, production and productivity of minor millets in Chhattisgarh

Dipti, D Nishad, D Prasad, MK Deshmukh, Reshma Rakse and Sandeep Sonkar

DOI: https://doi.org/10.33545/2618060X.2025.v8.i1Sg.2466

Abstract
The study has been made to forecast time series data from 2000 to 2023 of minor millets production in Chhattisgarh along with the evaluation of Statistical Models for forecasting of area, production and productivity of minor millets in Chhattisgarh. To explain the fluctuation in area, production, and productivity of minor millets in Chhattisgarh an effort has been made to fit linear, polynomial, ARIMA models and in order to develop a methodology that can accurately explain the variation in area, production and productivity in addition to the model selection for future forecasts, the highest coefficient of determination (R^2) and the lowest MAPE and RMSE values were used as selection criteria. As per the study, productivity increased from 2000 to 2023, while the area and output of minor millets exhibited a fluctuating constant and dropping tendency during the predicted period, which is up to five years. the prediction performance or better accuracy fitted models results in terms of MAE, RMSE, and R^2 for ARIMA, It is found that ARIMA (0,1,0) models and ARIMA (0,1,2) for area with lowest MAE (4.56) and RMSE (6.35) value and greater R^2 (0.89) and Productivity with lowest MAE (5.42) and RMSE (7.08) value and greater R^2 (0.75) has outperformed than other model respectively. The future projection of the minor millets crop showed a declining tendency for area and production whereas a minute increase in productivity. Erratic upward and downward i.e. constant trend shown for area and production however productivity projections show an upward tendency for future.

Keywords: ARIMA, Forcasting, time series data, MAE, RMSE, R^2

Introduction

Millets are small-grained cereals belonging to the Poaceae family that have adapted to grow well in arid and tropical environments. They are remarkably resilient in soil that is less fertile. India has become the world's largest producer of millets, which are indigenous to dry and semiarid countries such as central Asia and Africa. Year 2023 has been declared the International Year of Millets by the UN and India in an effort to increase awareness of their vital role in maintaining nutrition and food security. Millets have been grown as a traditional crop for more than 50 years, and because they are a basic diet and fodder for people, they have been dubbed "poor man's food." (Vashishth. N. *et al.* 2024) [11]. In Chhattisgarh (CG) minor millets like Ragi (Finger millet)**,** Kodo millet**,** Kutki (Little millet)**,** Sawa millet (Barnyard millet)**,** and Jowar (Sorghum) are primarily grown in tribal and rural regions, suited to the state's agro-climatic conditions. Key Growing Areas: Northern Chhattisgarh: Durg, Rajnandgaon, Kabirdham, Balod. Southern & Tribal Belt: Sarguja, Jashpur, Balrampur, Korba. Eastern & Central: Bilaspur, Mungeli, Raigarh. Millets have a remarkable nutritional profile because they are high in nutraceutical qualities and free of gluten and acid. They play a major role in promoting health and preventing disease, including diabetes. Mishra Pragya *et al.*, (2021). Trend on Total Food Grain Production in Different State of India. Worked out the trends in area, production and yield different parametric model like Polynomial, Logarithmic, Quadratic, Cubic, Compound, growth, and Exponential model were attempted (Nishad and Mishra, 2018) [6]. Saeed *et al,* (2000) [9] worked on forecasting and modeling Pakistani wheat production time series data.

From 1947–1948 to 1988–1989, they used time series data to apply the Box Jenkins ARIMA approach. According to the diagnostic examination, ARIMA (2, 2, 1) was a suitable model. With 95% confidence bounds, they projected wheat production from 1999–2000 to 2012–2013. Patra *et al.*, (2020) utilized the ARIMA Model to forecast the future of the Ragi crop with data spanning from 1985–1986 to 2017–2018. For the knowledge, the Auto Correlation Function (ACF) and Partial Auto Correlation Function (PACF) were computed. The Box-Jenkins ARIMA model was fitted appropriately. Mean Absolute Percentage Error (MAPE) and Root Mean Squared Error (RMSE) were used to test the model's validity. Production over the next five years was forecasted using the ARIMA (0, 1,1) model. Priyanka *et al.* (2020) [7] fitted different Linear, Non – Linear and time series ARIMA models on area, production and productivity of Sesame (*Sesamum indicum* L.) in Andhra Pradesh for the period 1965-66 to 2017-18. The Forecasted results showed for the area, production and productivity of Sesame crop for the year 2020-21 to be 51.66 thousand hectares, 17.64 thousand tonnes and 323.43 in kg/ha, respectively.

Material and Methods

The state wise time series data for the period from 2000 to 2023 about area production and productivity of minor millets in Chhattisgarh were taken from various official cites, *viz,* ICAR-Indian Institute of Millets Research (IIMR), Agricultural and Processed Food Products Export Development Authority (APEDA). Here, for the forecasting using ARIMA model and following data set can be made for the analysis. The goal of training is to enable the model to learn patterns relationships, or structures from data. In this study 90% data have been used for training purpose. The testing phase evaluates how the trained model performs on unseen data, which is crucial to assess its generalization ability. It is generally done by 10% of the whole data set followed by testing data set. Prity Kumari *et al.*, (2022). find the extent of influence of area and productivity on the production of minor millets in Chhattisgarh. For that we need an additive model with and error term. We have the identity, Production= Area x Productivity. Sahu *et al.*, (2018) [9]

Test for Randomness of the Residuals

A run is defined as a series of symbols of one kind separated by symbols of another kind. Randomness is a non-parametric test based on the number of turning points. Thus, to get a turning point, one needs at least there data points. The number of turning points is clearly one less than the number of runs up and down in the series. In only four of these ways would there be a turning point when the greatest or least value is in the middle (Nishad and Mishra.,2018) [6]

The run test is based on the number of runs (r). The residuals are changed to "+" or "-" depending on whether they are positive or negative. Hypothesis null (H_0) is presented by Evangilin. N.P (2020).

H_0: Randomness prevails in the residuals.

H_1: Remainders are not arbitrary

$$\text{Mean } \mu_r = \frac{2n_1n_2}{N} + 1$$

$$\text{Standard Deviation } \sigma_r = \sqrt{\frac{2n_1n_2(2n_1n_2-n_1-n_2)}{(n_1+n_2)^2+((n_1+n_2-1)}}$$

Linear and non-linear trend model

Name of models	Model
Linear equation	$\hat{Y}= a + bt$
Quadratic equation	$\hat{Y}= a+bt+ct^2$

Test for Normality of Residuals (Shapiro – Wilk, 1965)

The test for normality of the residuals was conducted using the Shapiro-Wilk (1965) statistic. On n residuals, the test is based. The letters $e_{(1)}, e_{(2)}, e_{(3)}, \dots e_{(n)}$ stand for these, which are placed in a non-decreasing order under the following given hypothesis by Dineshbhai D.K.,(2021) [2]

H_0: The residuals have a normal distribution.

H_1: The distribution of these is not regular

Test statistics given by

$W= s^2/ b$

Where $S^2 = \sum a (k) \{x_{(9n+1-k)} - x_{(k)}\}$

$b = \sum (x - \hat{x})^2$

Fitting the ARIMA model to Time Series

The concept of ARIMA model was developed by Box and Jenkins (1976). ARIMA model essentially require identification of three constants p, d, q *i.e.*, the order of AR terms (p), order of differencing (d) and the order of MA terms (q). Box and Jenkins (1976) established that these parameters can be obtained through trial and error approach after examining the Auto Correlation Function (ACF) and Partial Auto Correlation Function (PACF). The first step in developing ARIMA model is to examine data for stationarity. This can be identified through Auto Correlation Function (ACF) of actual data. If the auto correlation function does not die out rapidly, it indicates that the data is non-stationary. Under this situation, the auto correlation corresponding to most of lags are statistically significant. For reducing the data to stationarity, the data is therefore transformed by taking first order differences (d=1). If the auto correlation functions of differenced data indicate a rapid decrease, then it can be concluded that the transformed data is stationary. If not, again the data has to be transformed by taking second order differences (d=2). Continuing in a similar way as that of d=1, the order of differencing i.e., d can be determined. Mishra *et al.* (2024)

After determining the differencing order 'd' the order of auto regressive (p) and moving average (q) components, can be obtained as follows: If the auto correlation function corresponding to the transformed data decays after the q^{th} lag, then it is taken as MA (q) model; likewise, if partial auto correlation function indicates a decaying after p^{th}lag, it indicates existence of AR (p) model i.e., the characteristics p and q are determined on the basis of PACF and ACF of the stationary data. The ARIMA (p, d, q) model is then formulated as Evangilin.N.P.,(2020).

$W= s^2/ b$

$$S^2 = \sum a (k) \{x_{(9n+1-k)} - x_{(k)}\}$$

$$b = \sum (x - \hat{x})^2$$

Where

$Z_t = Y_t - \bar{Y}$ (Deviation of Y_t from mean Y)

Diagnostic Checking

RMSE: Stands for Root Mean Squared Error. It's a metric used to measure the average magnitude of errors between predicted and actual values

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(Y_i - \hat{Y}_i)^2}{N}}$$

MAPE: Stand for Mean Absolute Percentage Error. It measures the accuracy of a model by calculating the average percentage error between predicted and actual values.

$$MAPE = \frac{1}{N}\left|\frac{Y_i - \hat{Y}_i}{Y_i}\right|$$

R^2 (Coefficient of Determination): is a statistic that will provide some information about a model's Goodness of fit or R^2 is a statistical measure of how well the regression line approximates the actual data points a value of 1.0 means that the regression line fits the data perfectly, Priyanka *et al.*, (2020) [7].

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(Y - \hat{Y})}{(Y - \hat{Y})}$$

Results and Discussion

The time series plots (Fig.1) shown a declining trend, The ADF test was done to evaluate stationarity, and the results are presented in Table 1 provides the summary statistics for minor millets of area, production, and productivity. Table 2 revealed the Parameter estimation of the model. Table-3 provided the Run test for area, production and productivity. Table-4 provided Shapiro-Wilk test for area, production and productivity as shown underneath.

Table 1: Descriptive statistic for area, production and productivity of minor millets

Statistics Unit	Area '00'Hectares	Production '00'Tonnes	Productivity Kg/Ha
Observations	24	24	24
Minimum	44	15	156.54
Maximum	289.6	68.2	501
Mean	149.91	33.82	254.17
Median	144.66	29.19	228.46
Standard Deviation	77.02	14.12	92.95
Skewness	0.20	0.98	0.82
Kurtosis	1.68	2.75	4.26

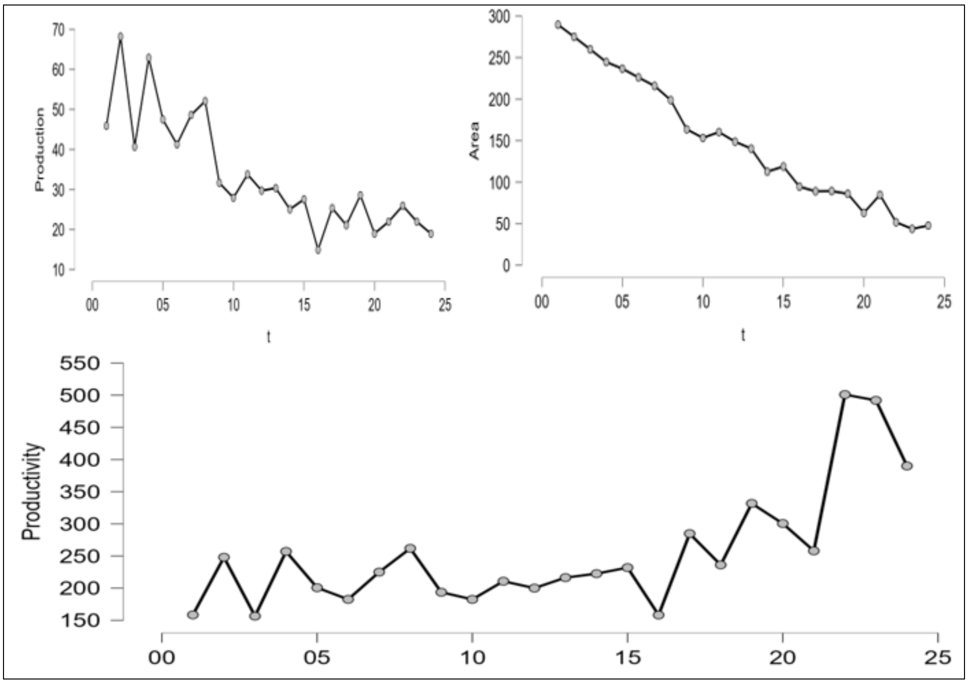

Fig 1: Time series plot Area, Production and Productivity

Table 2: Parameter estimations and an overview of the model

Aspects	Model	Regression Constant /coefficient				Goodness of fit		
		A	b_1	b_2	b_3	R^2	RMSE	MAE
Area	Linear	284.04	10.73	-	-	0.97	12.97	10.48
	Quadratic	309.01	16.49	0.23	-	0.98	8.44	7.102
Production	Linear	54.704	1.67	-	-	0.69	7.58	6.282
	Quadratic	62.67	3.51	0.073	-	0.75	6.90	10.48
Productivity	Linear	141	9.054	-	-	0.47	65.97	51.21
	Quadratic	243	14.48	0.94	-	0.67	52.27	39.22

Note:- when R^2 is high and RMSE and MAE are low, it confirms that the model is both accurate(low error) and well-fitted, Indicating` strong overall performance.

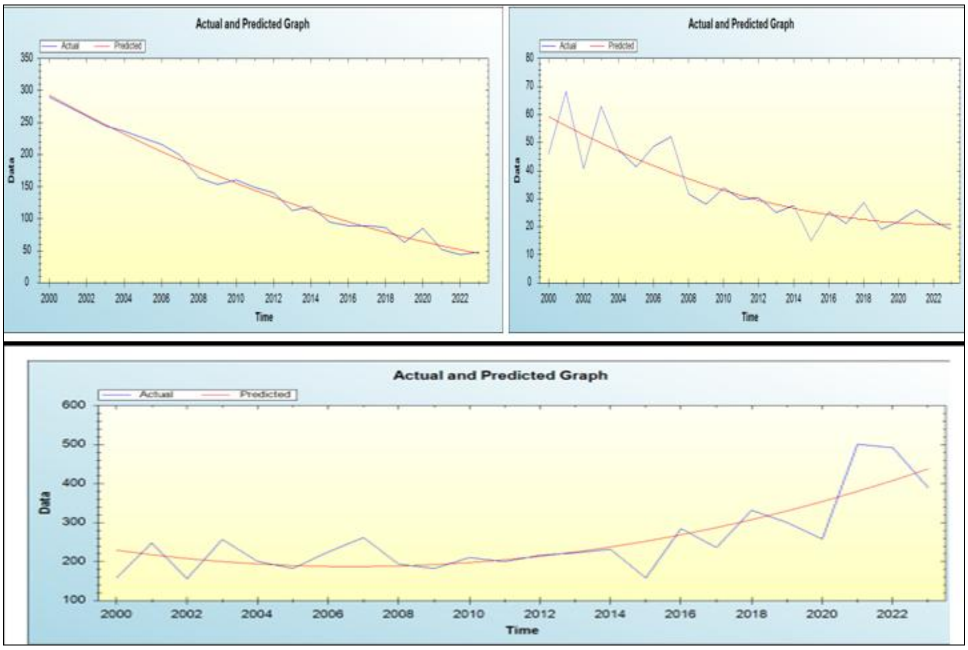

Fig 2: Quadratic Trend of Area, Production and Productivity

Table 3: Test for Randomness (Run test) area, production and productivity of minor millets

statistic	Area	Production	Productivity
No. of Observation	24	24	24
Run	2	2	8
E(p)	12.91	11.66	12.25
Inference	Random	Random	Random
Monte Carlo *p*	0.0001	0.0005	0.12

Table 4: Shapiro-Wilk Test (Residual) for area, production and productivity of minor millets

Normality test	W	P Value
Area	0.96	0.63
Production	0.973	0.74
Productivity	0.894	0.016

Note: High W-value & p-value > 0.05

Justification: Residuals follows a normal distribution, and model assumptions are met.

Table 5: Stationarity test (Unit root test) for minor millets area, production, productivity in Chhattisgarh

Minor Millets	Original		1st Differencing	
	Adf	p value	Adf	P value
Area	-1.21	0.86	-3.781	0.042
Production	-1.219	0.869	-3.781	0.042
Productivity	0.21943	0.99	-4.5696	0.01

Identification of parameter

The parameter'd' was already determined, so for the minor millets area, production and productivity in Chhattisgarh, the differencing parameter was set to first differencing (d=1). The parameters 'p' and 'q' were identified using the ACF and PACF of the first-differenced stationary series. The ACF and PACF for the minor millets area, production and productivity in Chhattisgarh are shown in the figure (3) which helped determine the orders of 'p' and 'q'. From the ACF, it was observed that a significant lag cut off the standard error limit, while the PACF showed that a certain number of lags cut off the standard error limit. Thus, for minor millets area, production and Productivity in Chhattisgarh the parameters 'p' and 'q' were identified accordingly, leading to the identification of the ARIMA (0, 1, 0), ARIMA (0,1,2), ARIMA (0,1,2) model based on the information from the ACF and PACF of the first-differenced series. Gandhi *et al.*, (2023) [3]

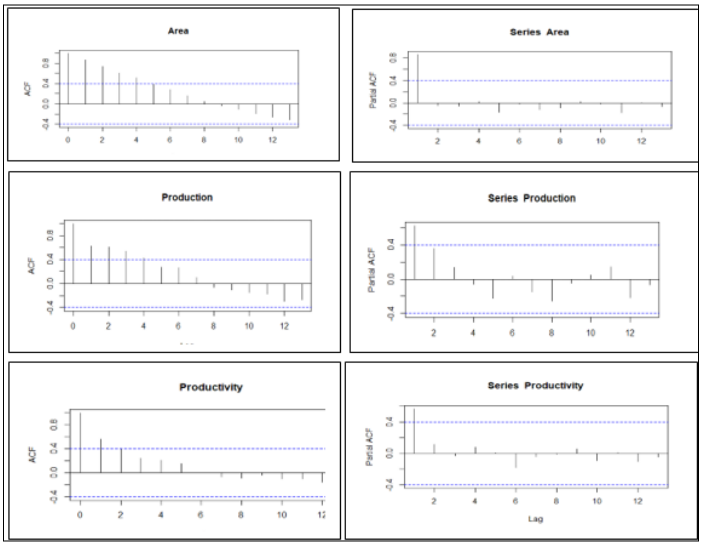

Fig 3: Acf and Pacf plot of Area, Production and Productivity
Estimation of parameter

All the models were estimated based on the identified values of p, d, and q for the minor millets area, production and productivity in Chhattisgarh, and the results are presented in Table the ARIMA (0, 1, 0), ARIMA (0,1,2), ARIMA (0,1,2) model produced the lowest AIC, the highest coefficient of determination R^2, and the lowest values for MAPE and MAE. The parameters for the ARIMA (0, 1, 0), ARIMA (0,1,2), ARIMA (0,1,2) model are provided in Table-6 where all coefficients were found to be statistically significant. Therefore, the ARIMA (0, 1, 0), ARIMA (0,1,2), ARIAM (0,1,2) model appears to be the best model for forecasting the future values of minor millets area, production and productivity in Chhattisgarh. However, the model still needs to be validated through diagnostic checks of the residuals.

Table 6: Evaluation of Best ARIMA models fitted to area, production and productivity under minor millets

Aspects	MODEL	MAPE	MAE	RMSE	R^2
Area	ARIMA (0,1,0)	8.34	4.56	6.35	0.89
Production	ARIMA (0,1,2)	17.33	5.56	7.34	0.58
Productivity	ARIMA (0,1,2)	17.82	5.42	7.08	0.75

Forecasting

After fitting the models, the area, production and productivity of minor millets have been forecasted for the next 5 years. Results of the minor millets production along with the lower and upper limit have been shown in Table-7,8,9 We have utilized ARIMA (0,1,0), ARIMA (0,1,2), ARIMA (0,1,2) with drift to estimate the 5year advance projection, and have plotted the results with their corresponding 95and 80 percent confidence interval. Gandhi *et al*., (2023) [3]

Table 7, 8, 9: Post sample period forecasts using ARIMA model of five year the minor millets area, production and productivity in Chhattisgarh

Year	Forecasted Value	Confidence Interval			
		Lo80	Ho80	Lo95	Ho95
2024	30.59	15.033	46.14	6.79	54.38
2025	19.93	2.41	37.46	-6.85	46.73
2026	9.288	-9.99	28.57	-20.2096	38.78
2027	2.363	22.267	19.54	-33.33	30.60
2028	2.014	34.41	10.39	-46.280	22.25

Year	Forecasted Value	Confidence Interval			
		L_o80	H_o80	L_o95	H_o95
2024	21.049	11.1007	30.99	5.83	36.26
2025	18.72	8.62	28.82	3.27	34.17
2026	17.25	6.34	28.17	0.56	33.951
2027	15.79	4.12	27.46	-2.058	33.644
2028	14.32	1.94	26.71	-4.609	33.26

Year	Forecasted Value	Confidence Interval			
		L_o80	H_o80	L_o95	H_o95
2024	571.44	491.94	650.94	449.86	693.03
2025	566.18	484.504	647.87	441.26	691.11
2026	580.51	482.55	678.48	430.68	730.34
2027	594.85	482.94	706.75	423.701	765.99
2028	609.18	484.88	733.47	419.09	799.27

Conclusion

It is to conclude that the evaluation of Statistical model for forecasting Area, Production and Productivity of minor millets in Chhattisgarh. The ARIMA model in this study highlights the importance of model selection for specific forecasting tasks. ARIMA models effectively capture linear trends in agricultural data related to minor millets (Area, production and Productivity). The size of the dataset plays a crucial role in time series modeling with larger datasets potentially leading to more accurate predictions and informed model selection. As per previous literature, The choice of model should consider the unique characteristics of the time series data and forecasting goals. Here we have observed that for trend analysis quadratic model was performed well for Area, Production and Productivity of Minor millets in Chhattisgarh. and ARIMA model was best fitted for area and productivity for future prediction on minor millets. Table-6 that ARIMA (0,1,0) models for Area with lowest MAE (4.56) and RMSE (6.35) value and greater R^2 (0.89) and ARIMA (0,1,2) for) Productivity with lowest MAE (5.42) and RMSE (7.08) value and greater R^2 (0.75) have outperformed.

Acknowledgement

Authors are thankful to Department of Agricultural Statistics & Social Science (L) College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya (IGKV) Raipur. Authors are also thankful to Pt. Shiv Kumar Shastri College of agriculture & Research station Surgi Rajnandgaon during the completion of my research.

References

1. Agricultural and Processed Food Products Export Development Authority (APEDA). Available from: https://apeda.gov.in
2. Dineshbhai DK. Estimation of trends in Gujarat's pulse crop area, production, and productivity: A time series analysis. Directorate of Agriculture, Gandhinagar, Gujarat; c2021.
3. Gandhi T, Saravanakumar V, Chandrakumar M, Divya K, Senthilnathan S. Forecasting pearl millet production and prices in Rajasthan, India: An ARIMA approach. Int J Stat Appl Math. 2023;SP-8(5):307-314.
4. Indian Institute of Millet Research (IIMR). Available from: https://www.millets.res.in
5. Mishra P, Sahu PK, Dhekale BS, Vishwajith KP. Modeling and forecasting of wheat in India and their yield sustainability. Indian J Econ Dev. 2015;11(3):637-647. DOI: 10.5958/2322-0430.2015.00072.4.
6. Nishad D, Mishra P. Trend on total food grain production in different states of India. Trends Biosci. 2018;11(9):2005-2008.
7. Priyanka EN, Murthy BR, Naidu MG, Aparna B. Statistical model for forecasting area, production and productivity of sesame crop (*Sesamum indicum* L.) in Andhra Pradesh, India. Int J Curr Microbiol Appl Sci. 2020;9(7):1156-1166.
8. Saeed S, Shamsuddin S, Khan M. Forecasting and modeling wheat production in Pakistan using Box-Jenkins ARIMA approach. J Agric Econ. 2000;51(2):261-272.
9. Sahu G, Nishad D, Lakhera ML, Mishra P, Joshi RP. Influence of area and yield on the production of maize in Chhattisgarh Plain. J Pharm Phytochem. 2018;7(2S):71-75.
10. Vashishth N, Maurya NK. Millet bran: Unveiling its potential health benefits. Int J Nutr. 2024, 1(2). DOI: 10.37591/IJN.