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AGRICULTURAL STATISTICS

Statistical Modeling and Trend Analysis of Jackfruit Production in the Districts of Kerala in India

Manish Kumar* and S. Vivek Menon

Department of Agricultural Statistics, Acharya Narendra Deva University of Agriculture & Technology, Ayodhya, India

*Corresponding author: manishstats88@gmail.com (**ORCID ID:** 0000-0002-4989-1612)

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ABSTRACT

The present paper examines growth and trend pattern analysis of jackfruit production in some selected districts of Kerala in India. The analysis is carried out by fitting statistical models, viz. linear and exponential models. The time series data on jackfruit during 2009-2018 is used for the analysis. The trend values have been obtained by fitting the respective models, and the validity of the models has been tested by using the Chi-square test statistic. It is revealed from the study that both models are valid for analyzing the growth and trend patterns of jackfruit production in the concerned districts. Moreover, the coefficient of determination is also computed to judge the suitability of the concerned models.

HIGHLIGHTS

- The growth and trend pattern of production of jackfruit is examined for the selected districts of Kerala.
- The present investigation is based on secondary time series data on jackfruit production during the period 2009-2018.
- The study reveals that both models are valid for analyzing the growth and trend pattern of jackfruit production.

Keywords: Time series, Linear model, Exponential model, Chi-square test, Coefficient of determination

Jackfruit (*Artocarpus heterophyllus L.*) is one of the largest nutritious fruits, rich in calcium, carbohydrates, fibers, proteins, vitamins, and other vital nutrients. It belongs to the Moraceae family and is native to the Western Ghats of India, and is commonly grown in Tropical and Near-Tropical regions of the world. India is the world's largest jackfruit producer, with 1830 thousand metric tons produced in the year 2017-2018 [*Source:* Horticulture Statistics Division, Government of India]. In raw form, jackfruit is consumed as vegetable curry, while in ripened form, it is consumed directly as fruit. Moreover, it can also be used in processed forms such as chips, pickles, etc. It is less sensitive to climate change as compared to other fruits and vegetables. It is a non-seasonal fruit that grows quickly, and does not require the application of any fertilizers. The by-products of jackfruit and the leaves of jack tree are used as fodder for livestock. The wood of the jack tree is widely utilized in manufacturing furniture, doors, and windows.

In the past as well as in recent times, several researchers and scientists have made remarkable developments relating to the usefulness and benefits of jackfruit; for instance, Baliga *et al.* (2011) and Ranasinghe *et al.* (2019) provided a detailed review of nutritional properties and benefits of jackfruit. Pua *et al.* (2007) utilized response surface methodology (RSM) to determine the optimum concentration of soy lecithin and gum arabic in producing drum-dried jackfruit powder, Ulloa *et al.* (2017) provided a detailed study on physicochemical and functional

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characterization of a protein isolate from jackfruit seeds, Anaya-Esparza *et al.* (2018) analyzed the effects of minimal processing technologies on jackfruit quality parameters. Sundarraj *et al.* (2018) conducted an experimental study to extract pectin from jackfruit wastes using oxalic acid.

It is well known that time series analysis has a significant role in various diversified fields of study. For instance, a time series analysis can be utilized to study the long-term trends in the area, production, and productivity of various crops and to forecast future values. An adequate model should be fitted to time series data to obtain a precise predicted trend value. The various models used for measuring the trend value in time series data are the linear model, exponential model, logistic model, and so on. The time series analysis of agricultural crops is of utmost importance for effective inventory and storage management of the crops so that they can be optimally utilized and minimized the loss.

Gardner *et al.* (1985) discussed the class of simple models which rely on the Holt-Winters procedure for seasonal adjustment of time series data and reviewed general exponential smoothing (GEM). Balanagammal *et al.* (2000) built ARIMA (autoregressive integrated moving average) models for time series data on various crops and predicted the future values. Rajarathinam *et al.* (2010) investigated the area, production and productivity trends, and growth rates of tobacco (*Nicotiana tabacum*) crops based on parametric and non-parametric regression models. Sharma *et al.* (2013) examined the growth and trend of pulse production in India using linear, semi-log, and compound growth functions. Tripathi *et al.* (2014) made a forecast on rice area, production, and productivity in Odisha state of India, by utilizing univariate ARIMA models, and the models' performances were validated by comparing with percentage deviation from the actual values and mean absolute percent error (MAPE).

Ramteke *et al.* (2015) studied the changes in the soybean (*Glycine max (L.) Merrill*) scenario over some time in Madhya Pradesh state of India, concerning area sown, production and productivity. Arti and Rai (2017) utilized the secondary time series data on sugarcane (*Saccharum officinarum*) in Uttar Pradesh. They revealed the percentage change and compound annual growth rate (CAGR) of sugarcane in terms of area, production and yield. Rahman and Bee (2019) assessed the trend and pattern of sugarcane production in Shahjahanpur district of Uttar Pradesh in India. Lal *et al.* (2020) analyzed the trend and growth rates of sugarcane production in districts of western Uttar Pradesh in India. Joshi *et al.* (2021) examined the compound growth rate and instability index of major crops in Nepal. Kartal and Arslan (2021) determined the most accurate prediction method based on comparing the methods used in irrigation performance, such as regression, time-series exponential smoothing, and time-series ARIMA model.

Nayak *et al.* (2021) examined the instability in sesamum production by using the instability index and conducted a decomposition analysis to determine the contribution of different components to the sesamum production. Saha *et al.* (2021) examined the growth rates of area, production, and yield of tea in Bangladesh before independence (1947–1970) and after independence (1972–2018) by using an exponential growth model. Singh *et al.* (2021a) analyzed the trend and change point detection of sugarcane production in India by applying several well-known non-parametric methods, viz. Pettitt's test, "Standard normal homogeneity test, and Buishand's range test. Singh *et al.* (2021b) computed spatial compound growth rates to determine the growth pattern and instability in the area, production, and productivity of sugarcane in major sugarcane growing states of India.

The objective of the present study is to examine the growth and trend patterns of jackfruit production in various districts of Kerala in India. For the present analysis, secondary time series data is utilized, and trend values have been obtained by fitting linear and exponential models to the concerned data. Moreover, the validity of the models has been tested by using Chi-square test statistics and coefficient of determination.

DATA AND METHODOLOGY

Source of Data

For the present study, secondary time series data on jackfruit production is considered, about the period 2009 to 2018 for various districts of Kerala in India. The time series data is obtained from the Department of Economics and Statistics, Government of Kerala, India.

Terminologies and Notations

In India, the state Kerala consists of a total of 14 districts, which exhibit various growth patterns of jackfruit production, viz. (i) increasing growth pattern, (ii) decreasing growth pattern, and (iii) constant growth pattern. For the present analysis, we have considered four districts: Kasargod (D1), Wayanad (D2), Idukki (D3), and Kottayam (D4). In these districts, we observe all three above mentioned cases of growth patterns.

Fitting of Statistical Models to the Data

To determine the trend and growth pattern of jackfruit production in the districts D1, D2, D3, and D4, we compute the trend values by fitting a linear model and an exponential model to the time series data on jackfruit as follows:

(A) Linear Model:

$$y_t = a + bt \qquad \ldots(1)$$

where y_t denotes the time series value at time t. The values of constants 'a' and 'b' are obtained on solving the following normal equations, which are obtained by using the principle of Least Squares.

$$\sum y_t = na + b\sum t \qquad \ldots(2)$$

$$\sum ty_t = a\sum t + b\sum t^2 \qquad \ldots(3)$$

(B) Exponential Model

$$y_t = ab^t \qquad \ldots(4)$$

Taking log on both sides of (4), we have:

$$Y_t = A + Bt \qquad \ldots(5)$$

where, $Y_t = \log y_t$, $A = \log a$ and $B = \log b$.

The normal equations for estimating 'A' and 'B' are as follows:

$$\sum Y_t = nA + B\sum t \qquad \ldots(6)$$

$$\sum tY_t = A\sum t + B\sum t^2 \qquad \ldots(7)$$

Finally, on solving (6) and (7), the values of 'a' and 'b' are obtained as follows:

$$a = \text{antilog}\,(A),\; b = \text{antilog}\,(B)$$

DATA ANALYSIS AND RESULTS

The secondary time series data on jackfruit production in districts D1, D2, D3, and D4, is depicted in Table 1. Also, the computed trend values on fitting linear and exponential models to the data in districts D1, D2, D3, and D4, are presented in Tables 2, 3, 4, and 5, respectively. Moreover, the model equations for linear and exponential trends in the respective districts are depicted in Table 6.

Table 1: Time series data on production of jackfruit in various districts of Kerala

Year	*Production (in million numbers) for the districts			
	D1	D2	D3	D4
2009	6	23	37	15
2010	7	21	50	16
2011	9	18	52	15
2012	8	19	64	16
2013	9	21	60	15
2014	10	16	61	15
2015	11	15	60	14
2016	12	17	57	17
2017	11	16	66	16
2018	12	13	61	14

Source: *As per the records of Department of Economics and Statistics, Government of Kerala, India.*

Table 2: Trend values for linear and exponential models in district D1

Year	Production (O_i)	Trend Values	
		Linear Model (L_i)	Exponential Model (E_i)
2009	6	6.6365	6.7086
2010	7	7.285	7.2104
2011	9	7.9335	7.7497
2012	8	8.582	8.3293
2013	9	9.2305	8.9523
2014	10	9.879	9.6219
2015	11	10.5275	10.3415
2016	12	11.176	11.1150
2017	11	11.8245	11.9463
2018	12	12.473	12.8399

Table 3: Trend values for linear and exponential models in district D2

Year	Production (O_i)	Trend Values	
		Linear Model (L_i)	Exponential Model (E_i)
2009	23	21.8819	22.1444
2010	21	20.991	21.0573
2011	18	20.1001	20.0236
2012	19	19.2092	19.04067
2013	21	18.3183	18.1059
2014	16	17.4274	17.2171
2015	15	16.5365	16.3719
2016	17	15.6456	15.5683
2017	23	21.8819	14.8040
2018	21	20.991	14.0773

Table 4: Trend values for linear and exponential models in district D3

Year	Production (O_i)	Trend Values	
		Linear Model (L_i)	Exponential Model (E_i)
2009	37	47.4543	46.7219
2010	50	49.527	48.6655
2011	52	51.5997	50.6899
2012	64	53.6724	52.7986
2013	60	55.7451	54.9950
2014	61	57.8178	57.2828
2015	60	59.8905	59.6656
2016	57	61.9632	62.1478
2017	66	64.0359	64.7331
2018	61	66.1086	67.4259

Table 5: Trend values for linear and exponential models in district D4

Year	Production (O_i)	Trend Values	
		Linear Model (L_i)	Exponential Model (E_i)
2009	15	15.4423	15.1097
2010	16	15.412	15.1459
2011	15	15.3817	15.1823
2012	16	15.3514	15.2188
2013	15	15.3211	15.2554
2014	15	15.2908	15.2919
2015	14	15.2605	15.3287
2016	17	15.2302	15.3655
2017	16	15.1999	15.4024
2018	14	15.1696	15.4394

Table 6: Model equations for linear and exponential trends in various districts

District	Linear Model	Exponential Model
D1	$y_t = 0.6485t - 1296.2$	$y_t = (8.9523)(1.0748)^t$
D2	$y_t = -0.8909t + 1811.7$	$y_t = (18.1059)(0.9509)^t$
D3	$y_t = 2.0727t - 4116.6$	$y_t = (54.995)(1.0416)^t$
D4	$y_t = -0.0303t + 76.315$	$y_t = (15.2553)(1.0024)^t$

In Tables 2, 3, 4 and 5, the term. 'O_i' denotes the observed value of production for the *i*-th year (*i* = 2009, 2010,…, 2018), 'L_i' denotes the linear trend value of production for the *i*-th year, and 'E_i' denotes the exponential trend value of production for the *i*-th year.

To demonstrate the relative influence of linear and exponential trend values on the observed values of jackfruit production for districts D1, D2, D3, and D4, the graphical plots are obtained and presented in Figs. 1 to 8.

Moreover, for testing the suitability of the linear and exponential models, we have computed the coefficients of determination (R^2) for the districts D1, D2, D3, and D4, by using the formula:

$$R^2 = 1 - \frac{\Sigma\left(Y - \hat{Y}\right)^2}{\Sigma\left(Y - \overline{Y}\right)^2} \qquad \ldots(8)$$

where Y denotes the observed value of $\overline{Y}$ is the mean value of the variable Y, and $\hat{Y}$ is the trend value of the variable Y obtained on fitting the respective statistical model (such as linear or exponential model, as the case may be) to Y.

The values of coefficients of determination (R^2), for the concerned districts, by fitting the linear and exponential models are obtained and presented in Table 7.

Table 7: Values of R^2 for various districts by fitting linear and exponential models

District	Linear Model	Exponential Model
D1	0.9	0.86
D2	0.75	0.75
D3	0.54	0.5
D4	0.0094	0.0093

From Table 7, it is revealed that:

(i) In each of the districts D1, D2, D3, and D4, the values of R^2 are nearly the same for both the

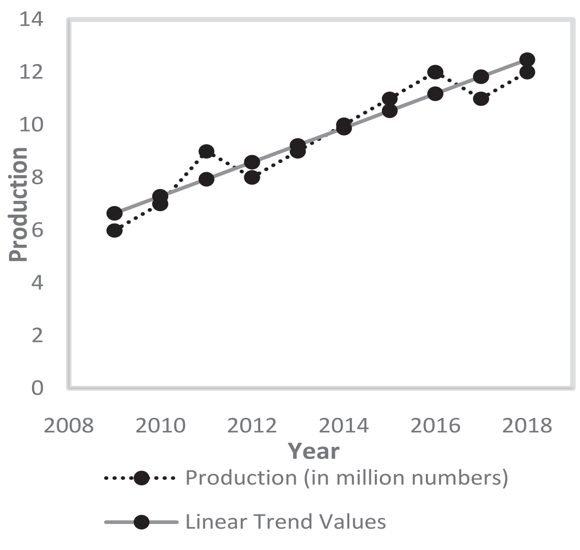

Fig. 1: Trend values for Linear Model in District D1

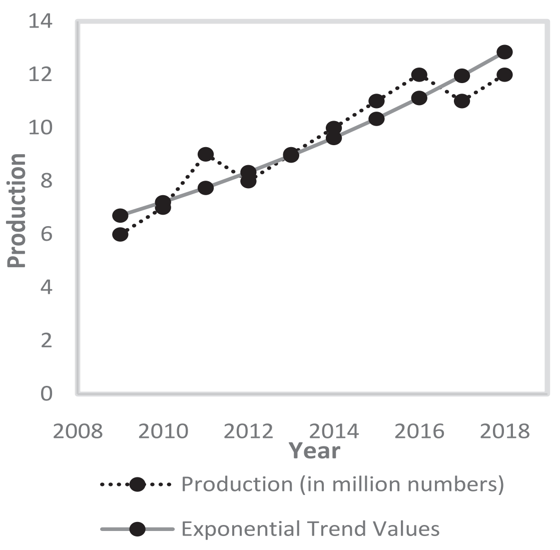

Fig. 2: Trend values for Exponential Model in District D1

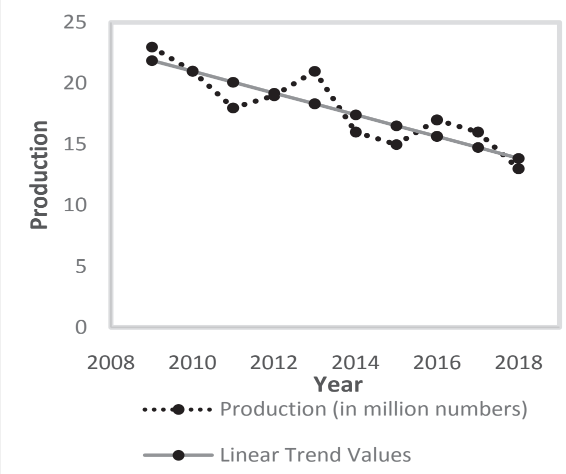

Fig. 3: Trend values for Linear Model in District D2

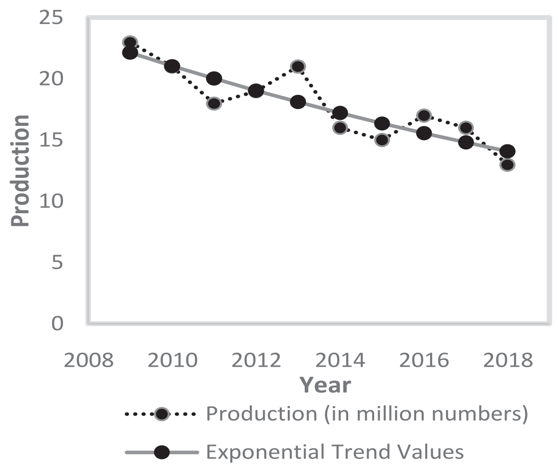

Fig. 4: Trend values for Exponential Model in District D2

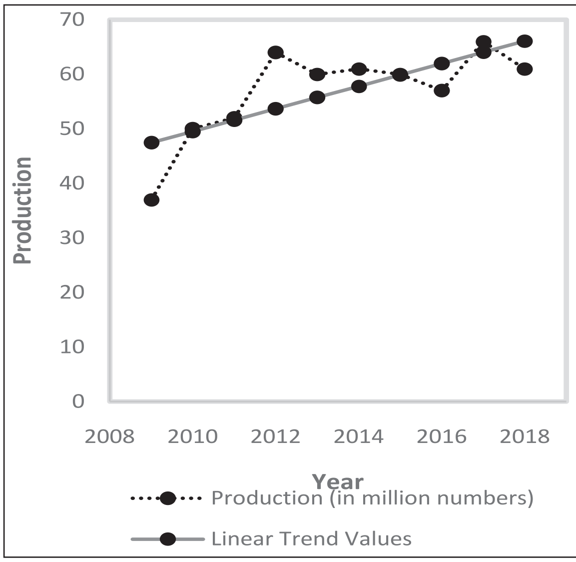

Fig. 5: Trend values for Linear Model in District D3

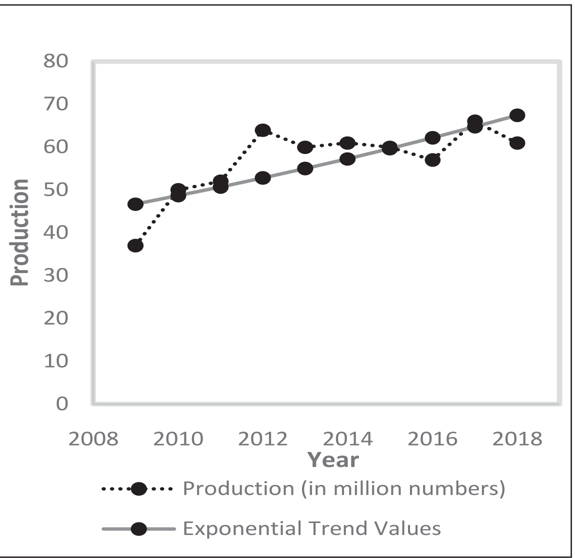

Fig. 6: Trend values for Exponential Model in District D3

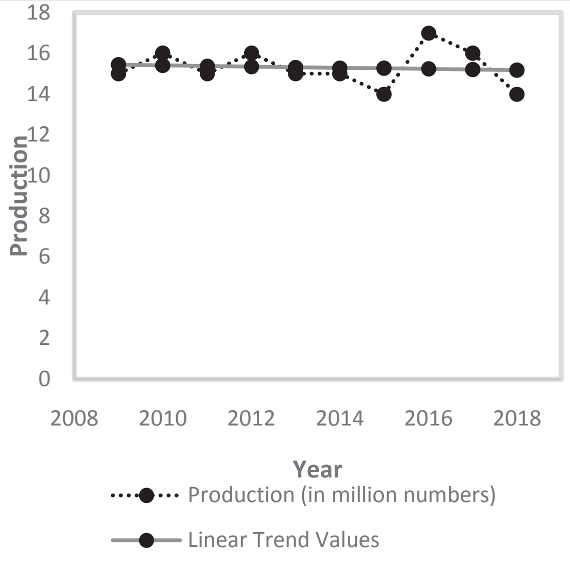

Fig. 7: Trend values for Linear Model in District D4

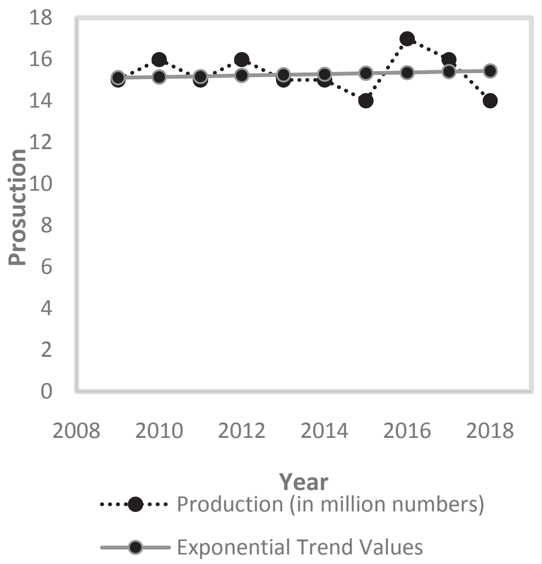

Fig. 8: Trend values for Exponential Model in District D4

linear and exponential models. Hence, both models are equally suitable for describing the trend and growth pattern of jackfruit production in the concerned districts.

(ii) In districts D1, D2, and D3, we observe that $R^2 \geq 0.5$, which implies that both the linear and exponential models are suitable for exploring the various changing trend patterns of jackfruit production in the concerned districts.

(iii) Due to the consistent growth pattern of jackfruit in the district D4, the variation of production (Y) from the mean value ($\overline{Y}$) is nearly the same as the variation of production from the trend value $\hat{Y}$ (i.e., linear trend value and exponential trend value, as the case may be). Symbolically, for district D4, we have $\sum(Y-\hat{Y})^2 \cong \sum(Y-\overline{Y})^2$. Hence, in the district D4, the value of R^2 is infinitesimally small.

Formulation of Hypotheses

We test the following null hypotheses:

H_{0A}: Linear model fits the given time series data on jackfruit production.

H_{0B}: Exponential model fits the given time series data on jackfruit production.

Against the following respective alternative hypotheses:

H_{1A}: Linear model does not fit the given data on jackfruit production.

H_{1B}: Exponential model does not fit the given data on jackfruit production.

The above-mentioned hypotheses are tested for the concerned districts D1, D2, D3, and D4 of Kerala state in India.

Hypotheses Testing and Validation

The chi-square values for the fitted linear and exponential models (i.e., χ_L^2 and χ_E^2) in the concerned districts D1, D2, D3, and D4 of Kerala, have been computed, and the findings are depicted in Table 8. The chi-square values by fitting the concerned models have been obtained using the below mentioned formulae:

$$\chi_L^2 = \sum_{i=1}^{n} \frac{\left(O_i - L_i\right)^2}{L_i} = \sum_{i=1}^{10} \frac{\left(O_i - L_i\right)^2}{L_i},$$

$$\chi_E^2 = \sum_{i=1}^{n} \frac{\left(O_i - E_i\right)^2}{E_i} = \sum_{i=1}^{10} \frac{\left(O_i - E_i\right)^2}{E_i}$$

where the terms 'O_i', 'L_i' and 'E_i' have been utilized from the Tables 2, 3, 4, and 5, for the districts D1, D2, D3, and D4 of Kerala.

Table 8: Values of χ^2 for various districts by fitting linear and exponential models

District	Chi-square values	
	Linear model (χ_L^2)	Exponential model (χ_E^2)
D1	0.4197	0.5531
D2	0.1172	1.2121
D3	5.6506	6.2319
D4	0.5263	0.5475

The tabulated values of chi-square at 1% and 5% levels of significance with 9 degrees of freedom are given, respectively, by

$$\chi_{0.01,9}^2 = 21.67 \text{ and } \chi_{0.05,9}^2 = 16.92$$

From Table 8, we observe the following results:

(i) $\chi_{LDi}^2 < \chi_{0.01,9}^2$ and $\chi_{LDi}^2 < \chi_{0.05,9}^2$ $(i = 1,2,3,4)$

(ii) $\chi_{EDi}^2 < \chi_{0.01,9}^2$ and $\chi_{EDi}^2 < \chi_{0.05,9}^2$ $(i = 1,2,3,4)$

Hence, given the above results, we accept the null hypotheses H_{0A} and H_{0B}, and conclude that the linear model and the exponential model fit the given time series data on jackfruit production for the districts D1, D2, D3, and D4 of Kerala.

DISCUSSION AND CONCLUSION

The present paper deals with the time series analysis of jackfruit production in various districts of Kerala in India. The growth and trend patterns of jackfruit production have been examined by fitting statistical models, viz. linear model, and exponential model, to the concerned time series data for various districts. It has been observed that the linear and exponential trend values are nearly the same as the observed values for the respective districts D1 (Kasargod), D2 (Wayanad), D3 (Idukki) and D4 (Kottayam) of Kerala. Hence, both the linear and exponential models are appropriate for predicting the future trends of jackfruit production in the concerned districts of Kerala.

It has been observed from the results of Section 2 that the districts D1 and D3 exhibit increasing growth patterns of jackfruit production, while district D2 exhibits a decreasing growth pattern. Moreover, in district D4, we observe a consistent growth pattern. Furthermore, in all these districts, the growth patterns are uniform instead of irregular. The jackfruit production in district D3 remains the highest compared to the other mentioned districts.

To test the "goodness of fit" of the linear and exponential models for the districts D1, D2, D3 and D4, the chi-square test statistic values (i.e., χ_L^2 and χ_E^2) have been computed for the respective districts. These values are then compared with the tabulated values of chi-square at 1% and 5% significance levels. It has been observed that both models fit the given time series data on jackfruit production for the concerned districts.

Moreover, based on values of the coefficient of determination (R^2), we conclude that both the linear and exponential models are suitable for analyzing the trend patterns of jackfruit production.

Hence, based on the basis of based on above results, we conclude that both the linear and exponential models are suitable for exploring the growth and trend patterns of jackfruit production in the concerned districts of Kerala. The present study could be enhanced further by considering the scenario of jackfruit production in the rest of the districts of Kerala. Moreover, there is a high potential for increasing the area, production and processing of jackfruit in the Kerala state of India. Considering the benefits and usefulness of jackfruit, the potential farmers can be encouraged to its cultivation. Also, jackfruit cultivation involves fewer resources than the other horticultural crops and is also a significant source of income generation, and doubling of farmer's income.

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