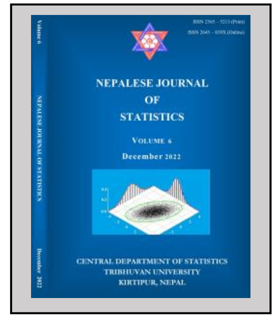
A Comparison of Trend Models for Predicting Tea Production in Bangladesh



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ABSTRACT

Background: Tea (*Camellia sinensis*) is a manufactured popular beverage that is mostly consumed around the globe including Bangladesh. Tea consumptions are increasing day by day due to its healthcare effects in the world as well as in Bangladesh. To meet the ever-growing population's demand in Bangladesh, it is important to predict the production of tea.

Objective: Although it is found in the literatures that studies have examined different trend models for tea and agricultural crops, no such study has been found to choose best trend model for predicting the production of tea in Bangladesh. Therefore, an attempt is made to identify the best trend model based on different model selection criterion for the prediction of tea production in Bangladesh.

Materials and Methods: Six trend models namely linear, logarithmic, inverse, quadratic, cubic, and compound were applied on tea production dataset (1976 to 2020) collected from the Food and Agriculture Organization Corporate Statistical Database (FAOSTAT) website. For justification of the model, different model section criteria have been checked.

Results: The results showed that the compound trend model is the most suitable among considered trend models for predicting the tea production in Bangladesh. Finally, the yearly growth rate of tea production for the period from1976 to 2020 found the compound growth rate of tea production in Bangladesh as 1.02 per year. It is important to note that for the next five years, forecasted increasing rate could be 4840.91 tonnes for the yearly tea production of Bangladesh. Furthermore, remarkable increased progresses of production have been noticed as 23585.7 and 21691.01 tonnes, respectively for the years 2019 and 2020 by the re-estimated model due to the proper nourishing and maintaining the input supply chain from government ends.

Conclusion: In the respect of the growing demand, the best-fitted trend model applied herewith through outlier checking and related sophisticated justification tools on the tea production area could help to accumulate knowledge for the practitioner.

Keywords: Autocorrelation, GDP, outlier, tea production, time series, trend models.

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INTRODUCTION

Tea is a common and widely liked beverage in every stages of the society. It is prepared from the leaves of tree *Camellia sinensis* (Arancon, Edwards, Dick, & Dick, 2007). Tea consumptions are increasing day by day due to its healthcare effects in the world as well as in Bangladesh. In Bangladesh, a leading foreign reserve obtained from tea (Rahman, Sarker, Huda, Nurullah & Zaman, 2011) and it is an export based crop (Rahman, Jianchao, Adnan, Islam, Zhao & Sarker, 2020) in the agricultural sector of Bangladesh. According to the history, tea is originated from China and recent times it is treated as one leading demanded drink in the trade and commerce (Ahmad & Hossain, 2013). Almost in a year, sixty-three million kilograms of tea is produced in Bangladesh from about 57210 hectares of land (BTB, 2012) and contributing almost 0.81% of the GDP (BTB, 2002).

Considering the demand and export benefit in context of global and local market, it could be a matter of investigation of the growing trend in the competitive market in the statistical viewpoints. As such, it is needed to check the existing trend model based research in the assorted area and crops. Various trend models are available in the literature among them Gupta, Sahu, Sanyal and Pal (1999); Karmokar and Imon (2008) have investigated some trend models using the production of principal crop, rice. Similarly, Singh, Kumar, Paikra and Kusro (2014) have examined growth models for paddy crop. Another study done by Aparna, Shareef, Raju and Srinivasa (2008) focused on growth rates for some major vegetables in Andhra Pradesh state of India through compound growth model. In area, production, and yield of major crops in Bangladesh, growth and trend analysis was performed by Akhter, Sarker and Das (2016). Saha, Mehedi Adnan, Sarker and Bunerjee (2021) applied exponential growth model to observe the growth of area, production, and yield of tea in Bangladesh. Although most of the studies pull out good outcomes but they didn't make comparison among trend models.

Rahman (2021) explored the current pattern of tea production with the influences of rainfall on tea yield. Linear, quadratic, and exponential trend models are applied in Raza, Naheed, Anwar, and Masood (2015) to explore tea import in Pakistan. Samantaray and Ashutosh (2012) observed the trend of tea industry in India applying regression, time series analysis and cluster analysis. Majumder, Bera and Rajan (2012) focused on area and production of tea globally and found a compound growth rate of tea was 0.42 percent during 1991. An estimation of predicted values for the production of different crops were presented by Ahuja (1987). Mishra, Sahu, Bajpai and Nirnjan (2012) concentrated on previous trends of tea production in India and also export scenario. This study expressed production of tea grew 4.95 percent per annum in the study period. Darvishi and Indira (2013) presented a rise in the growth rate for post liberalization in India annually. In Bangladesh, very few amount of research was conducted on tea production. No research has been found in literature to compare trend models on tea production in Bangladesh and also assessed any best trend model among them.

Since no such study have been found to compare the trend models for the tea production of Bangladesh, it could contribute to boost up the producers and concerning policymakers in their decision purpose and their betterment. The tougher justification of considered best models with proper diagnostic checking in statistical aspects should be exemplary due to the assumption aspects as desired in the objectives and the research hypothesis as well as in the forecasted ground.

METHODOLOGY

Trend models

In literature there have been several trend models applied to justify the production trends. Six models have considered like, Linear trend, Logarithmic trend, Inverse trend, Quadratic trend, Cubic trend, and Compound trend models for estimating and forecasting the tea production. Denoting the production of tea by Y, the trend models are as follows.

- The Linear model can be expressed as:
  $$Y = \beta_0 + \beta_1\, Time + u$$
- The Logarithmic model is:
  $$Y = \beta_0 + \beta_1 \log Time + u$$
- The inverse model is:
  $$Y = \beta_0 + \frac{\beta_1}{Time} + u$$
- The Quadratic model is:
  $$Y = \beta_0 + \beta_1 Time + \beta_2 Time^2 + u$$
- The Cubic Model is:
  $$Y = \beta_0 + \beta_1 Time + \beta_2 Time^2 + \beta_3 Time^3 + u$$
- The Compound model is:
  $$Y = \beta_0 \beta^{Time} + u$$

where the assumption of the associated error term (u) has normal distribution with zero mean and constant variance.

Model's performance checking

The goodness of fit of the trend models are checked by using R-square and adjusted R-square. Although the large R-square values specify the better fit of the data, sometimes over-fitting the model may produce misleadingly high R-squared values and a lessened ability to make predictions. In such a case, adjusted R-square is applicable for the models involving too many predictors and higher order polynomials. The normality assumption of random error term is very essential to get a good R-square and adjusted R-square model. Besides this existence of unusual observation or outliers in the data are very unfavorable to get a good fitted model as well as further analysis (Karmokar & Imon, 2008). Therefore, in this study we applied different graphical approach to check these two important assumptions. Normal probability-probability plots are very useful and practiced to check normality of error. The ordered residuals are plotted against their cumulative probabilities and the resulting points should create a straight line if normality holds. The exodus from the straight line shows non-normality of error. Besides this graphical approach some analytical method of tests are seen to use commonly for checking the normality of the errors. They are Shapiro-Wilk's normality test, The Anderson-Darling normality test, the Jarque –Bera test (JB) test etc. (Das & Imon, 2016). Among all of these, we use Jarque–Bera test (JB) test for its simplicity and easy applications. The normality assumption is tested applying Jarque-Bera test can be defined as:

$$JB = \frac{a_1^2}{\lambda_1} + \frac{(a_2-3)^2}{\lambda_2}$$

Here, a_1= Sample skewness of the residuals; a_2= Sample kurtosis of the residuals

$\lambda_1 = 6/n$ and $\lambda_2 = 24/n$

Also, n is the sample size. The statistic JB follows asymptotic chi-square distribution with degrees of freedom 2. The time series plots of residuals and Durbin Watson test used to investigate the autocorrelation of the residuals.

Treatment on the outlier observations

The existence of outliers of the data can be recognized by deleted Studentized residuals or R-Student residuals proposed by Cook and Weisberg (1982). Influential observation is identified by Cook's Distance proposed by Cook (1977). Also, boxplot is a graphical presentation of data to detect the outlier problems and we applied boxplot in the tea production data set to check the outlier or influential observations. These observations with outlier often produces faulty results that leads to incorrect decision. Therefore, treatment on the outlier observations is very important. There are three ways to obtain robust estimates in presence of outlier observations as deleting the observations with outlier from the dataset, applying the robust methods, and applying conventional methods on the modified dataset (Hasan, Rana, Begum, Rahman and Mollah, 2018a; Hasan, Rana, Begum, Rahman and Mollah, 2018b; Hasan, Badsha & Mollah, 2020). Among these first one is cooperatively easy to use.

Dataset

A secondary data of tea production of Bangladesh from 1976 to 2020 is used in this research and pulled out from FAOSTAT (https://www.fao.org/faostat/en/#data/FBS) (FAO, 2022).

RESULTS AND DISCUSSION

Model's performance checking on real data in presence of outliers

The scatter diagrams are given in the Fig. 1. It is evident that there is nearly linear pattern though the deviation has observed in the pick points of this diagram. So that another scatter diagram between log production of tea and time (in year) presented here. Though the pattern of the scatter diagram has deviation from straight line relationship so we can check also compound, quadratic, cubic, inverse, logarithmic trend models beside linear trend model. As we applied ordinary least squares (OLS) method, we have to check normality assumption properly. In this regard, normal probability plots of residuals are presented here. Also, these plots showed that compound trend model slightly obeys normality assumption of the random errors as maximum points lie or very near to the straight line in the normal probability plot though that is not in the satisfactory level. In the normal probability plot for compound trend model the points are derivate from the straight line in the upper side. So, these plots depicts that there may be outlier problem in the data. This tea production data is a time series data that's why by the time series (TS) plot of residuals, we need to check autocorrelation problem. An observation comes from the time series plot of residual that there is first order positive autocorrelation for all trend models.

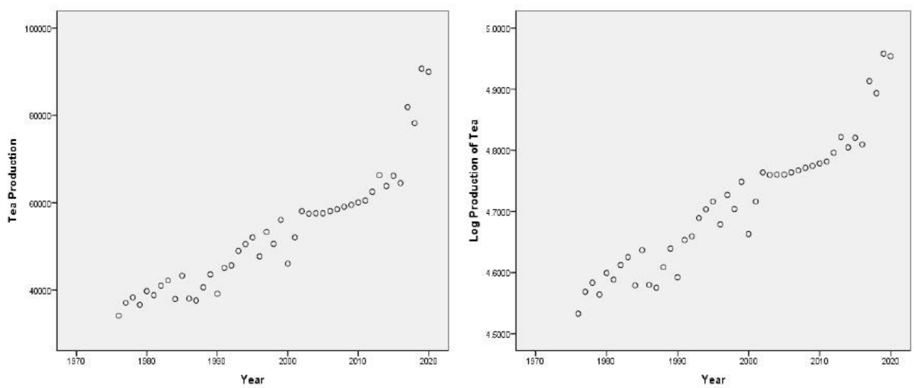

Fig. 1. Scatter diagram of production of tea and log production of tea.

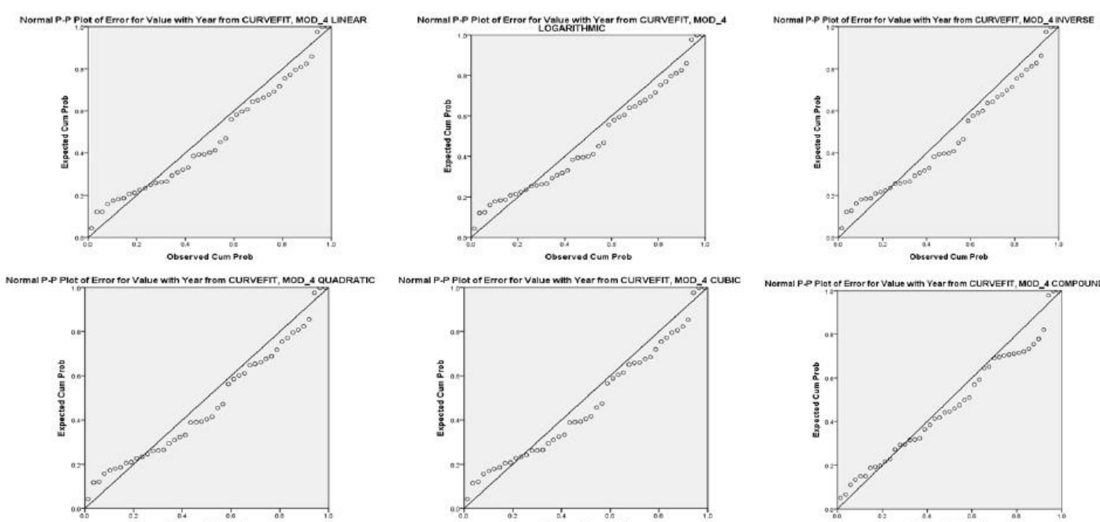

Fig. 2. Normal probability plot of residual of six trend models.

Now, Table 1 presents the coefficients of linear, logarithmic, inverse, quadratic, cubic, and compound trend models. The R^2 and adjusted R^2 values are almost similar for linear, logarithmic, inverse, quadratic, and cubic trend model but the values are greater for compound model. Also F statistics shows highly significant for all of these trend models. Jarque-Bera (JB) test statistic shows that no one trend models follow normality assumptions at 5% level of significance. Darbin-Watson (DW) test statistic presents extreme autocorrelation for linear, logarithmic, inverse, quadratic, cubic, and compound trend models.

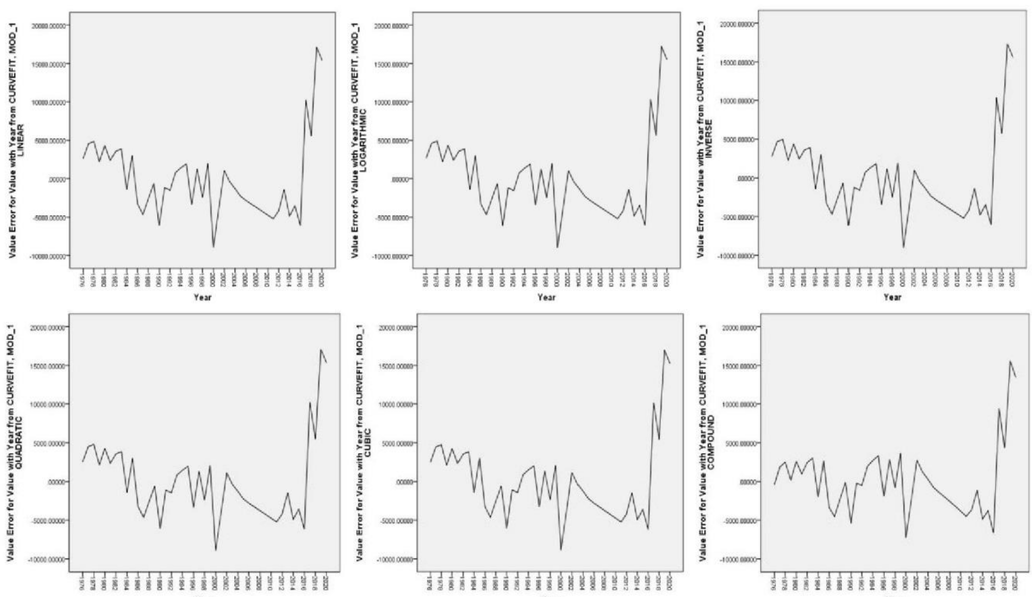

Fig. 3. Time series plot of residuals for six trend models.

Table 1. Diagnostics of trend models of tea production.

Estimates /Statistics	Linear	Logarithmic	Inverse	Quadratic	Cubic	Compound
$\widehat{\beta_0}$	-1901273.58	-14788418.68	2004428.92	-924850.39	-599377.06	1.055E-011
$\widehat{\beta_1}$	978.12***	1952849.63***	3898778736.67 ***	-75.89***	-37.52***	1.02***
$\widehat{\beta_2}$				0.25***	-75.14***	
$\widehat{\beta_3}$					8.18E-005***	
R^2	0.86	0.86	0.86	0.86	0.86	0.91
Adj. R^2	0.86	0.85	0.85	0.85	0.85	0.91
F	261.36***	258.79***	256.24***	263.96***	266.58***	463.61***
JB (5.99)	14.94	15.15	15.34	14.75	14.55	14.45
DW	0.75	0.74	0.74	0.75	0.76	0.97

*** indicates significant at 1% level of significance.

Treatment on the outlier observations

The existence of outlier problem is checked by applying boxplot. This plot shows that the observation no. 44 and 45 are problem here for the linear, logarithmic, inverse, quadratic, cubic, and compound trend model. All of these trend models have two observations with outlier.

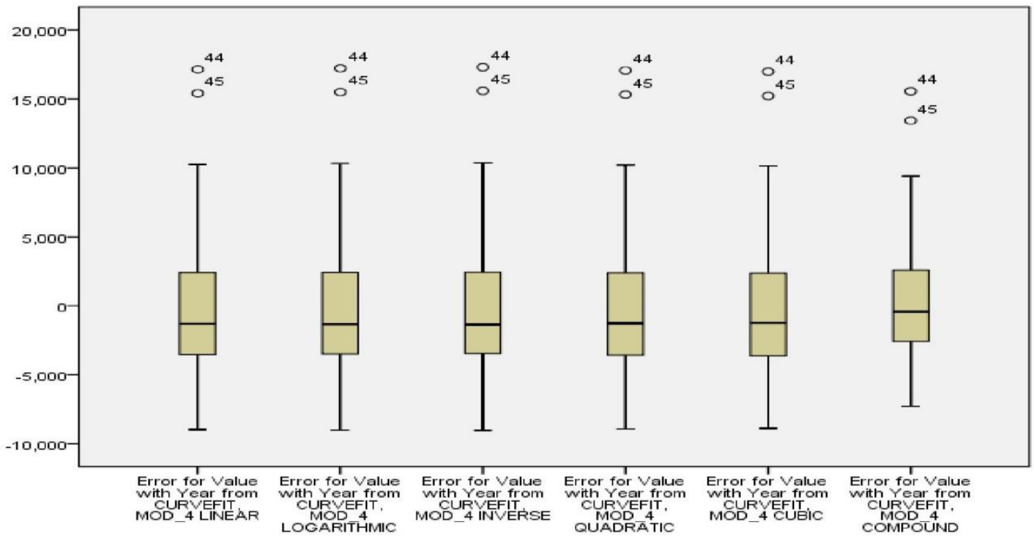

Fig. 4. Boxplot of the residuals for trend models.

Descriptive statistics of tea production in presence of outlier observations with the position of outlier observation and years are enlisted in the Table1.

Table 2. Descriptive statistics of tea production.

Tea production (in tonne)	Min	Max	Mean	Outlier	Outlier
	34097	90685	53005.76	90685	89931
Year	1976	2019	N/A	2019	2020
Outlier Position	N/A	N/A	N/A	44	45

Median replacement in the outlier position

The boxplot shows that the observation no. 44 and 45 are outlier for the linear, logarithmic, inverse, quadratic, cubic, and compound trend model. After replacing the outlier values of tea production by median (52000 tone), all diagnostics of trend models of tea production in Bangladesh are presented in the following table.

Table 3. Diagnostics of trend models of tea production replacing outliers with median in 44 and 45 Observation.

Statistic	Linear	Logarithmic	Inverse	Quadratic	Cubic	Compound
A	-1469453.06***	-11506727.66***	1572179.10***	-1469453.06***	-1469453.06***	5.266E-009
B	761.13***	1520817.37***	-3038581710.37***	761.13***	761.13***	1.02***
C				-7.991***	-7.99***	
D					-4.04***	
R^2	0.79	0.79	0.79	0.79	0.79	0.82
Adjusted R^2	0.78	0.78	0.78	0.78	0.78	0.82
F	164.79***	164.90***	165.00***	164.79***	164.79***	207.62***
JB	28.23	27.59	26.96	28.23	28.23	48.43
DW	1.29	1.29	1.29	1.29	1.29	1.24

*** indicates significant at 1% level of significance.

The JB and DW test statistic shows no better result for normality and autocorrelation assumptions. So that after removing outliers, again we check the performance of different trend models for tea production in Bangladesh.

Model's performance checking in absence of outlier on real data

Impacts of outliers have been examined in different aspects. The median replacement technique and single outliers' replacements were followed. However, removed outliers from the data set shows better fit of compound trend model considering the DW statistics. The R^2 and adjusted R^2 values are near to each other though the compound model shows higher R^2 and adjusted R^2 values. F statistic shows that all of these trend models are significant.

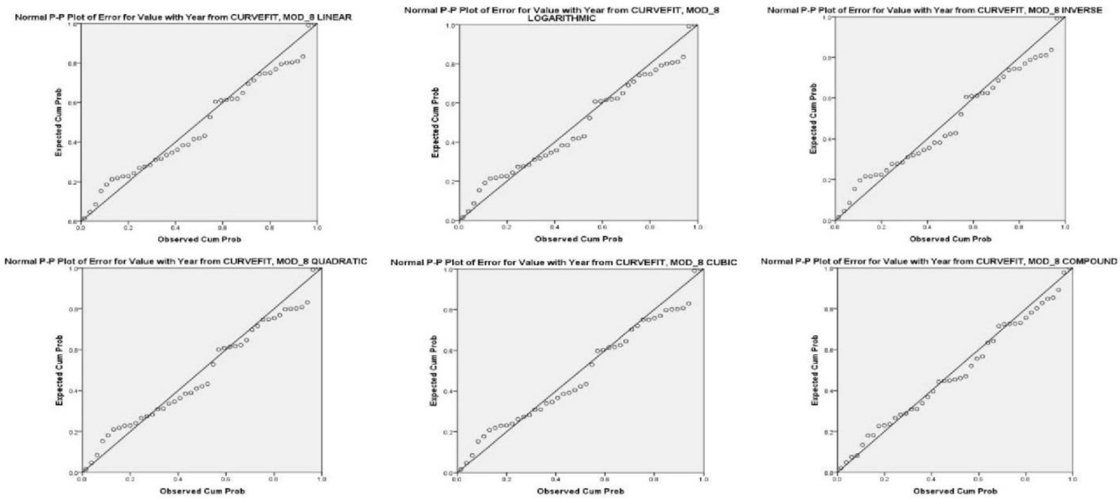

Fig. 5. Normal probability plot of residuals without outliers.

Jarque-Bera test shows only the compound trend model follows the normality assumption at 5% level of significance among these six trend models. Normal probability plot depicts the same results for the normality assumption. Also autocorrelation is moderate for compound trend model comparing with other five trend models by the Darbin-Watson test statistic value. Comparing to the trend models with the application of various statistical diagnostics, finally it is clear that the compound trend model is somewhat suitable for tea production considered herewith. Therefore, the estimated compound trend model is

$$\hat{y} = (1.11E\text{-}010)*1.02^t, \text{ where t = Time (in year).}$$

So the compound growth rate of tea production in Bangladesh is 1.02 per year.

Real data analysis using compound model

The best performed compound model (given in Fig. 6) for tea production in Bangladesh is applied to forecast the production for next five years from 2021 to 2025 and it is found the forecasted production for the year of 2021 as 69400.07 tonnes. The predicted values showing increased pattern up to the last predicted year 2025 and the remarkable predicted value is 74240.98 tonnes.

CONCLUSION

Because of its simplicity and easy understanding, the traditional trend models are very popular among the practitioners in any production related data. Nevertheless, complexity may arise while the data points contain possible outliers. Although the last two years of the dataset showed different pattern were noticed as outlier but in practical the increasing production may be good symptom of ensuring the production oriented inputs and the improvement of caring system of the concerning authorities. It may be the good policies implemented by the government. The present situation showed its difficulties by showing consecutive observations marked as outlier. It is very risky to replace or remove the two extreme productions as outlier. Because the continuous outlying fashion may be the suspecting behavior of shifting, the production margin from the year begins that increasing or decreasing pattern. As such, we re-estimated the considered trend models from the data of 1976 to 2020 and remarkable progress in production have been achieved by the increased production of 23585.7 and 21691.01 tonnes, respectively for the years 2019 and 2020.

Table 4. Diagnostics of trend models of tea production without outlier.

Estimates /Statistics	Linear	Logarithmic	Inverse	Quadratic	Cubic	Compound
$\widehat{\beta_0}$	-1681459.97	-13110667.67	1782490.72	-815473.06	-526811.09	1.11E-010
$\widehat{\beta_1}$	867.67***	1731974.84***	-3457112740.22***	-48.98***	-24.03***	1.02***
$\widehat{\beta_2}$				0.22***	-48.09***	
$\widehat{\beta_3}$					7.25E-005***	
R^2	0.89	0.89	0.89	0.90	0.90	0.92
Adj. R^2	0.89	0.89	0.89	0.89	0.89	0.92
F	366.23***	363.27***	360.31***	369.17***	372.11***	495.54***
JB (5.99)	9.00	9.22	9.29	8.79	8.58	5.68**
DW	1.14	1.13	1.13	1.15	1.16	1.54

*** and ** indicates significant at 1% and 5% level of significance respectively.

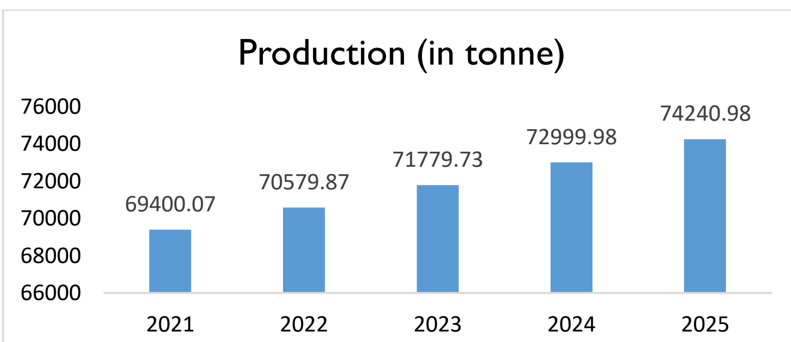

Fig. 6. Year-wise forecasted production of tea by compound model.

The demand of manufactured popular social beverage tea is rising in Bangladesh world as well as in the world. Additionally, In Bangladesh tea is an export based crop and adding a significant amount of foreign reserve every year (Rahman et al., 2011; Rahman et al., 2020). Therefore, in Bangladesh researcher, policy makers have given their attention for improving tea cultivation and production. Considering these issues, it is very important to predict or forecast future tea production Bangladesh. Therefore, in this study, we have checked suitability of six trend models like linear, logarithmic, inverse, quadratic, cubic, and compound on FAOSTAT tea production dataset (1976 to 2020) for predicting future tea production in Bangladesh. The value of R^2 and adjusted R^2 are 0.92 and 0.92 respectively for compound model which displays large values comparing other model's R^2 and adjusted R^2 values without outlier. The corresponding F value is significant. In addition, the JB test statistics values display that only compound trend model obeys normality assumption at 5% level of significance comparing other five models. The Mean Absolute Percentage Error (MAPE) of the compound trend models have shown the lower values 1.001 in compare with the other selected models justifies the best fit of the data. Observing these results, it is concluded that the compound trend model is the best forecasting model among the considered models in this study for predicting the growth rate and future production tea in Bangladesh. Applying the compound trend model on the mentioned dataset we found yearly growth rate of 1.02 times on average. This model also forecasted the yearly tea production from 2021 to 2025 and found that it might be increased to 4840.91tonnes for the next eleven years in Bangladesh. Nonetheless, this growth rate will not be sustainable for long time since the land area of Bangladesh suitable for tea production is limited. Therefore, the agricultural researchers have to pay attention in developing and caring about the yield with corresponding tea varieties to meet the ever-growing demand of tea of Bangladesh.

CONFLICT OF INTEREST

The authors declared that they have no conflict of interest.

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