ANSF APPLIED AND NATURAL SCIENCE FOUNDATION

Journal of Applied and Natural Science
11(4): 778 - 784 (2019)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Estimation of annual compound growth rates of guava (*Psidium guajava* L.) fruit in Haryana using Non linear model

Pardeep Panghal
Department of Mathematics and Statistics, Chaudhary Charan Singh Hisar Agriculture University Hisar-125004 (Haryana), India
Manoj Kumar*
Department of Mathematics and Statistics, Chaudhary Charan Singh Hisar Agriculture University Hisar-125004 (Haryana), India
Sarita Rani
Department of Mathematics and Statistics, Chaudhary Charan Singh Hisar Agriculture University Hisar-125004 (Haryana), India

*Corresponding author. E-mail: m25424553@gmail.com

Article Info
https://doi.org/10.31018/jans.v11i4.2175
Received: October 7, 2019
Revised: November 12, 2019
Accepted: November 17, 2019

How to Cite
Panghal, P. *et al.* (2019). Estimation of annual compound growth rates of guava (*Psidium guajava* L.) fruit in Haryana using Non linear model. *Journal of Applied and Natural Science*, 11(4): 778 - 784 https://doi.org/10.31018/jans.v11i4.2175

Abstract
Computation of growth rates plays an important role in agricultural and economic research to study growth pattern of a various commodities. Many of the research workers used the parametric approach for computation of annual growth rate but not use the concept of non-linear model. In this paper, an attempt has been made to study growth rates of guava for three districts (Hisar, and Kurukshetra) and Haryana state as a whole using different non-linear models. The time series data on annual area and production of guava (*Psidium guajava* L.) in different districts of Haryana from 1990-91 to 2015-16 were collected to fit non linear models. Growth rates were computed through best fitted non-linear models. It was found that Logistic model could be best fit for computation of growth rates of area for guava fruit in Hisar and Kurukshetra district and Haryana state as a whole whereas Gompertz model was best fit for Yamunanagar district based on high R^2 and least MSE and RMSE values. It was also observed that monomolecular model was best fit for production of guava fruits in Hisar and Yamunanagar district whereas Logistic model was best fit for production of guava fruit in Kurukshetra and Haryana state as a whole because of high R^2 and least MSE and RMSE values. R and excel software have been used for fitting the non linear model and computation of growth rates for area and production of guava fruit for the year 1990-91 to 2015-16. None has been used the non linear model growth model for computation of annual growth rate of guava fruit for area and production of Haryana state. But in this work non linear growth model has been used for computation of growth rate instead of parametric approaches.

Keywords: Annual growth rate, Coefficient of determination, Non linear model, Relative mean square error

INTRODUCTION

Guava (*Psidium guajava* L.) is one of the important commercial fruit crops in India and introduced in 17thcentury. It is a rich source of vitamin C, pectin, calcium and phosphorus and is used for the preparation of processed products like jams, jellies and nectar. Guava and its plant parts have great medicinal values for curing diabetes and diarrhoea etc. Leaves of guava are used for curing diarrhoea and also for dyeing and tanning.It is grown in both tropical and sub-tropical region up to 1,500 m above sea level however good quality guava are produced in river basins.In India, total area under guava was 254.87 thousand hectare in 2015-16 and total production was 4047.79 thousand MT in 2015-16 Haryana state as a whole (National Horticulture Board, India 2015-16)

Guava is the 4thmost important fruit after mango, banana and citrus. It is native to tropical America where it occurs as a wild plant. Over the last three years area has increased from 246 thousand hectare to 262 thousand hectare whereas production has increased from 3994 thousand MT to 3648 thousand MT. The value of output produced from Guava in India has increased from Rs. 303931 to Rs. 399693 (Lakhs) whereas the value of output in Haryana has increased from Rs. 10328 to 14827 (Lakhs) since 2011-12 to 2016-17 (Anonymous, 2015).

Estimation of growth rates plays an important role in agricultural and economic research to study growth pattern of a particular commodity. Many research workers have studied the growth rates for area, production and productivity of various agricultural commodities (Rajarathinam *et al*., 2010, Acharya, *et al*., 2012, Singh, et al. 2018, Singh, *et al*., 2019 and Kumar, 2019) on the usual parametric approach. Prajneshu and Chadran (2005) pointed that method of computation of growth rates on the basis of semi-logarithmic growth model has a number of serious lapses and therefore the conclusions drawn are not statistically sound. Keeping in view the above the present study has been undertaken to estimate the compound annual growth rates for area and production for three individual districts (Hisar, Yamunanagar and Kurukshetra) and Haryana state on the basis of non linear growth models like Logistic, Monomolecular and Gompertz model.

MATERIALS AND METHODS

Non linear growth models *viz*. Logistic model, Monomolecular and the Gompertz model were used to estimate the compound annualgrowth rates of area and production of guava fruit in Haryana State. The type of model needed in a specific situation depends on the type of growth that occurs. In general, growth models are mechanistic in nature rather than empirical. The descriptions of studied models are as:

Monomolecular model: This model describe the progress of a growth situation in which it is believed that rate of growth at any time is proportional to resource yet to be achieved, i.e.

$$\frac{dy}{dt} = a(c - y) \qquad (1)$$

Where a and c are the intrinsic growth rate and carrying capacity of the system, On integration, we get the model

y(t) = c-(c-b)*exp(-a*t) + e(t),

where, y_0 is the value of y (t) at t = 0.

This model is also called negative exponential model (Campbell and Madden, 1990).

Logistic Model: It is given by the

$$\frac{dy}{dt} = a`y(1 - \frac{y}{c}) , \qquad (2)$$

on integration, we get

y(t) = c/(1+b*exp(-a*t))

The graph of y(t) versus t is elongated. S-shaped and the curve is symmetrical about its Inflexion.

Gompertz Model: This model has sigmoid type of behavior and is found quite useful in the biological work. However, unlike logistic model, this is not symmetric about its point of inflexion. This model is given by the differential equation.

$$\frac{dy}{dt} = ay\,\mathrm{Ln}(c/y) \qquad (3)$$

Where, the symbol “Ln” denotes “natural logarithm” Integration of this equation yields

y(t) = c*exp(-b*exp(-a*t)) + e(t),

where y(t) denotes the variable under study at time t, ‘a’ denote the intrinsic growth rate, ‘c’ the carrying capacity of the system

Fitting of non-linear growth model: In nonlinear model it is not possible to solve the non-linear equations exactly the only alternative is to employ iterative procedures. Parameter estimate in non-linear regression can be obtained by the method of least squares. There are three methods to obtain approximate analytical solutions by employing iterative procedures:

Linearization (Taylor series) method.

Steepest descent method

Levenberg-Marquardt’s method

The details of these methods along with their merits and demerits are given in Draper and Smith (1998). The linearization method uses the results of linear least square theory in a succession of stages. However, neither this method nor the steepest descent method is ideal. The steepest descent method is able to converge on true parameter values even though initial trial values are far from the true parameter values, but this convergence tends to be very slow at the later stages of the iterative process.

On the other hand, the linearization method will converge very rapidly provided the vicinity of the true parameter values has been reached, but if initial trial values are too far removed, convergence may not occur at all. Mostly used method for computing non-linear least squares estimators is the Levenberg Marquardt’s method. The Levenberg-Marquardt method combines two minimization methods. The gradient descent method and the Gauss-Newton method. In the gradient descent method, the sum of the squared errors is reduced by updating the parameters in the steepest-descent direction. In the Gauss-Newton method, the sum of the squared errors is reduced by assuming the least squares function is locally quadratic, and finding the minimum of the quadratic. It is good in the sense that it almost always converges and does not ‘slow down’ at the latter part of the iterative process.

Goodness of fit for criteria for selection of model: There is no single technique to evaluate goodness of fit criterion to access the suitability of models fitted. This is generally assessed by the coefficient of determination, R^2. In addition to R2, root mean square error (RMSE) and mean absolute error were also used as the selection criteria for evaluation of model. The details of the criteria is given below

Coefficient of determination (R2): It is calculated using the following formula

$$R^2 = 1 - \frac{RSS}{TSS}$$

Where RSS is the residual sum of square, TSS is the total sum of square. The coefficient of determination lies always between 0 to 1, and the model is considered to be best fitted if R2 is close to unity.

The mean squared error (MSE): It is the average of the squared difference between estimated value and observed value and is given as

$$MSE = \frac{\Sigma(y_i - \hat{y})^2}{n}$$

Root mean square error (RMSE): It is a kind of generalized standard deviation and was calculated as follows:

$$RMSE = \sqrt{\frac{\Sigma(y_i - \hat{y})^2}{n}}$$

RMSE value is one of the most important criteria to compare the suitability of used growth curve models. Therefore, the best model is the one with the lowest RMSE.

Compound growth rate and annual growth rate: CGR should be computed by first identifying that which model is best fitted for the path followed by response variables over time. For Monomolecular, Logistic and Gompertz models, annual growth rates pertaining to the period Ri, (i = 0, 1, 2,….., n-1) where n =no. of data points.

Monomolecular model: Rt=a*(c/y(t)-1) (4)

Logistic model: Rt=a*(1-y(t)/c) (5)

Gompertz model: Rt= a*ln(c/y(t)) (6)

Where, a = Intrinsic Growth rate, c = Some limiting growth value or carrying capacity y(t) = response variable at any time t. We can obtain Compound Growth rate over a given time period by taking arithmetic mean or average.

SPSS, R and Excel has been used to fit the models and computation of annual growth rate.

RESULTS AND DISCUSSION

The perusal of data presented in Table 1 revealed the area and production of guava fruit in the district of Hisar, Yamunanagar, Kurukshetra and Haryana state as a whole for the year 1990-91 to 2015-16. The data has been taken from site of Horticultural board Haryana (Anonymous, 2015).

Table 2 shows the parameter estimation and selection criteria for the Hisar, Yamunanagar, Kurukshetra and Haryana state as a whole using different models i.e. Monomolecular, Logistic and Gompertz model for area of Guava from 1990-91 to 2015-16. From the above table it is concluded that Logistic model has maximum value of R^2 and least value of MSE and RMSE for Hisar, Kurukshetra and Haryana state as a whole. Therefore, Logistic model found to be the best fit for computation of compound growth rates and predicted value for Hisar, Kurukshetra and Haryana State as a whole. From the table, it is also concluded that Gompertz model found to be the best fit for Yamunanagar because of maximum value of R^2 and least value of MSE and RMSE and the same was used for computation of growth rate and predicted value of area of Guava in Yamunanagar.

Table 3 shows the predicted value and annual

Table 1. Area and production of guava fruit in different districts of Haryana.

Year	Hisar		Yamunanagar		Kurukshetra		Haryana	
	Area (ha)	Production (MT)	Area (ha)	Production (MT)	Area (ha)	Production (MT)	Area (ha)	Production (MT)
1990-91	140	1100	80.6	680	90.2	760	1734.55	14500
1991-92	165	1400	89	750	103	850	1909	15645
1992-93	169	1125	102	1100	93	515	2172	16350
1993-94	196	1500	103	1400	114	670	2509	22301
1994-95	216	2900	115	1050	135	1100	2778	22700
1995-96	258	2300	127	2300	152	1250	3160	25500
1996-97	308	4100	161	1550	175	1200	3540	25850
1997-98	228	1700	197	1600	200	1300	4062	30450
1998-99	263	3000	218	5400	229	1450	4648	44771
1999-00	295	4000	278	2012	253	2018	5194	43709
2000-01	320	3100	349	2305	275	2068	5728	40092
2001-02	328	1400	387	3914	280	2644	5944	41226
2002-03	329	3300	477	4107	290	3010	6173	54870
2003-04	359	3500	564	1844	216	2045	6026	48111
2004-05	324	3305	268	2734	185	1887	3998	40780
2005-06	344	2350	300	2073	200	1072	4622	34878
2006-07	455	2140	319	1622	214	1080	5346	39725
2007-08	503	2950	388	1781	227	1020	6133	42199
2008-09	576	1750	461	2065	227	534	6973	48209
2009-10	614	2300	516	1846	249	510	7817	55840
2010-11	865	3140	530	5460	351	2934	9339	71612
2011-12	918	2820	567	4390	365	1250	9651	87056
2012-13	973	12610	679	8142	405	1585	10379	107559
2013-14	982	10005	735	8800	422	2850	10669	125043
2014-15	976	12200	785	7000	426	3805	10843	136730
2015-16	983	13130	821	12800	468	6259	11211	152184

Table 2. Parameter estimation and selection criteria for fitting of Non-linear growth model for area of guava in Hisar district of Haryana during period 1990-91 to 2015-16.

Parameters	Monomolecular	Logistic	Gompertz
Hisar			
A	6.91×10^{-05}	0.086	0.009
B	-14.39	285.74	11.29
C	513562.70	34338.49	8764795
R2	0.849	0.942	0.941
MSE	14288.86	5452.47	5616.24
RMSE	119.53	73.84	74.94
Yamunanagar			
A	0.007	0.084	0.017
B	5.57	46.38	6.00
C	194072.60	5088.61	38591.13
R2	0.868	0.885	0.886
MSE	7461.49	6530.49	6447.45
RMSE	86.37	80.811	80.29
Kurukshetra			
A	0.008	0.053	0.006
B	75.73	9293644	9417
C	87357.11	10203.30	1310758.00
R2	0.784	0.811	0.808
MSE	2725.651	2379.72	2415.046
RMSE	52.20777	48.78237	49.14312
Haryana			
A	0.008	0.066	0.009
B	924.74	134.52	8.18
C	2618520.00	296053.90	7352944.00
R2	0.895	0.92	0.92
MSE	999292.40	758216.10	758762.80
RMSE	999.65	870.76	871.07

Table 3. Predicted value and annual growth rate on the basis of best fitted model for area of Guava in Hisar, Yamunanagar, Kurukshetra and Haryana state as a whole from 1990-91 to 2015-16.

Years	Hisar		Yamunanagar		Kurukshetra		Total Haryana	
	Logistic Predicted Area(ha)	Annual Growth Rate through Logistic Model	Gompertz Predicted Area(ha)	Annual Growth Rate through Gompertz Model	Logistic Predicted Area(ha	Annual Growth Rate through Logistic Model		Annual Growth Rate through Logistic Model
1990-91	130.51	0.0857	105.62	0.1003	115.79	0.0524	2331.85	0.0655
1991-92	142.23	0.0856	116.56	0.0986	122.13	0.0524	2488.97	0.0654
1992-93	155.00	0.0856	128.43	0.0970	128.81	0.0523	2656.60	0.0654
1993-94	168.91	0.0856	141.28	0.0954	135.85	0.0523	2835.40	0.0654
1994-95	184.06	0.0855	155.17	0.0938	143.28	0.0523	3026.11	0.0653
1995-96	200.56	0.0855	170.15	0.0922	151.12	0.0522	3229.50	0.0653
1996-97	218.54	0.0855	186.30	0.0907	159.38	0.0522	3446.41	0.0652
1997-98	238.11	0.0854	203.66	0.0892	168.10	0.0521	3677.70	0.0652
1998-99	259.42	0.0854	222.32	0.0877	177.30	0.0521	3924.31	0.0651
1999-00	282.62	0.0853	242.32	0.0862	186.99	0.0520	4187.21	0.0651
2000-01	307.88	0.0852	263.75	0.0848	197.22	0.0520	4467.46	0.0650
2001-02	335.37	0.0852	286.67	0.0833	208.01	0.0519	4766.16	0.0649
2002-03	365.29	0.0851	311.14	0.0819	219.38	0.0519	5084.48	0.0649
2003-04	397.86	0.0850	337.25	0.0806	231.38	0.0518	5423.67	0.0648
2004-05	433.28	0.0849	365.05	0.0792	244.04	0.0517	5785.03	0.0647
2005-06	471.82	0.0848	394.61	0.0779	257.39	0.0517	6169.96	0.0646
2006-07	513.73	0.0847	426.02	0.0766	271.47	0.0516	6579.93	0.0645
2007-08	559.30	0.0846	459.34	0.0753	286.31	0.0515	7016.47	0.0644
2008-09	608.85	0.0845	494.65	0.0741	301.97	0.0514	7481.23	0.0643
2009-10	662.70	0.0843	532.01	0.0728	318.49	0.0513	7975.92	0.0642
2010-11	721.20	0.0842	571.49	0.0716	335.91	0.0513	8502.36	0.0641
2011-12	784.76	0.0840	613.17	0.0704	354.28	0.0512	9062.45	0.0640
2012-13	853.77	0.0839	657.12	0.0692	373.66	0.0511	9658.20	0.0638
2013-14	928.68	0.0837	703.40	0.0681	394.10	0.0510	10291.71	0.0637
2014-15	1009.96	0.0835	752.09	0.0669	415.65	0.0508	10965.18	0.0636
2015-16	1098.13	0.0832	803.25	0.0658	438.39	0.0507	11680.92	0.0634

Table 4. Predicted value and annual growth rate on the basis of best fitted model for Production of Guava in Hisar, Yamunanagar, Kurukshetra and Haryana state as a whole from 1990-91 to 2015-16.

Years	Hisar		Yamunanagar		Kurukshetra		Haryana	
	Monomolecular Predicted Production (MT)	Annual Growth Rate through Monomolecular Model	Monomolecular Predicted Production (MT	Annual Growth Rate through Monomolecular Model	Predicted Production (MT)	Annual Growth Rate through Logistic Model		Annual Growth Rate through Logistic Model
1990-91	2145.43	0.0008	1902.82	0.0009	641.50	0.0353	11049.44	0.1020
1991-92	2147.49	0.0011	1904.76	0.0012	664.88	0.0366	12231.04	0.1020
1992-93	2150.30	0.0015	1907.39	0.0016	690.04	0.0380	13539.00	0.1020
1993-94	2154.13	0.0021	1910.94	0.0022	717.17	0.0395	14986.83	0.1020
1994-95	2159.33	0.0028	1915.74	0.0029	746.53	0.0411	16589.49	0.1020
1995-96	2166.40	0.0038	1922.22	0.0039	778.39	0.0428	18363.54	0.1020
1996-97	2176.02	0.0051	1930.97	0.0053	813.09	0.0447	20327.29	0.1020
1997-98	2189.12	0.0070	1942.80	0.0071	851.03	0.0468	22501.05	0.1020
1998-99	2206.93	0.0094	1958.78	0.0095	892.68	0.0491	24907.27	0.1020
1999-00	2231.15	0.0126	1980.36	0.0126	938.62	0.0516	27570.80	0.1020
2000-01	2264.12	0.0169	2009.53	0.0168	989.54	0.0544	30519.16	0.1020
2001-02	2308.96	0.0226	2048.94	0.0223	1046.31	0.0576	33782.81	0.1020
2002-03	2369.96	0.0299	2102.18	0.0293	1109.98	0.0611	37395.47	0.1020
2003-04	2452.95	0.0393	2174.12	0.0383	1181.91	0.0650	41394.47	0.1020
2004-05	2565.84	0.0512	2271.30	0.0496	1263.80	0.0695	45821.10	0.1020
2005-06	2719.42	0.0657	2402.61	0.0633	1357.89	0.0747	50721.12	0.1020
2006-07	2928.36	0.0830	2580.01	0.0797	1467.11	0.0807	56145.12	0.1020
2007-08	3212.59	0.1029	2819.69	0.0985	1595.43	0.0878	62149.16	0.1020
2008-09	3599.26	0.1249	3143.52	0.1193	1748.36	0.0962	68795.26	0.1020
2009-10	4125.29	0.1482	3581.03	0.1415	1933.71	0.1064	76152.08	0.1020
2010-11	4840.91	0.1719	4172.14	0.1641	2163.03	0.1190	84295.60	0.1020
2011-12	5814.42	0.1947	4970.75	0.1861	2454.04	0.1350	93310.02	0.1020
2012-13	7138.80	0.2157	6049.74	0.2066	2835.53	0.1560	103288.40	0.1020
2013-14	8940.48	0.2343	7507.52	0.2249	3357.46	0.1847	114333.80	0.1020
2014-15	11391.49	0.2501	9477.07	0.2407	4114.87	0.2264	126560.50	0.1020
2015-16	14725.85	0.2632	12138.06	0.2540	5313.54	0.2923	140094.60	0.1020

Table 5. Parameter estimation and selection criteria for fitting of Non-linear growth model for production of Guava Hisar district of Haryana during period 1990-91 to 2015-16.

	Hisar		
Parameters	**Monomolecular**	**Logistic**	**Gompertz**
a	-0.308	0.141	0.008
b	2143.90	2.81×10^{8}	19.47
c	2139.69	8.87E+10	7.52×10^{10}
R2	0.789	0.666	0.653
MSE	3005835	4753023	4940479
RMSE	1733.73	2180.14	2222.71
	Yamunanagar		
a	0.301	8.62E-06	0.008
b	1901.38	1.00	18.00
c	1897.28	0.30	2.47×10^{10}
R2	0.791	0.787	0.674
MSE	1980197	2017401	3083415
RMSE	1407.19	1420.35	1755.97
	Kurukshetra		
a	6.18×10^{-5}	4.90×10^{-6}	0.005
b	539.54	1.00	13.94
c	145670.70	0.08	7.36×10^{8}
R2	0.295	0.513	0.343
MSE	1236395	853663	1151604
RMSE	1111.93	923.93	1073.12
	Haryana		
a	5.44×10^{-5}	0.102	0.007
b	-3926.21	7.63E+08	15.48
c	78076667	7.62×10^{12}	4.87×10^{10}
R2	0.734	0.895	0.885
MSE	4.15×10^{8}	1.64×10^{8}	1.79×10^{8}
RMSE	20371.38	12823.79	13380.22

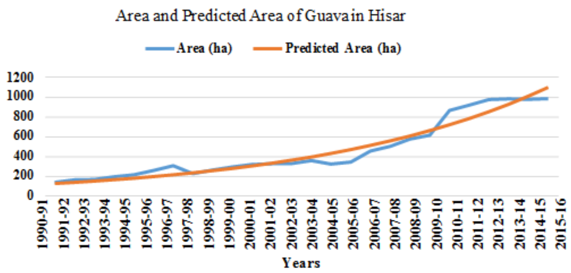

Fig. 1. *Showing the actual and predicted value of area of Guava in Hisar district for the year 1990-91 to 2015-16 through Logistic model.*

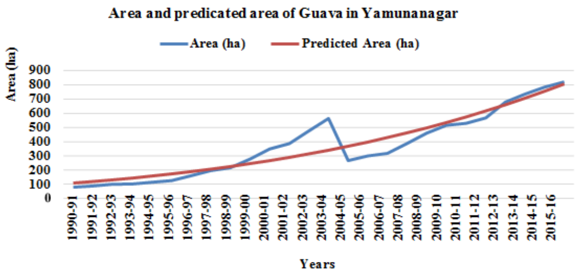

Fig. 2. *Showing the actual and predicted value of area of Guava in Yamunanagar district for the year 1990-91 to 2015-16 through Gompertz model.*

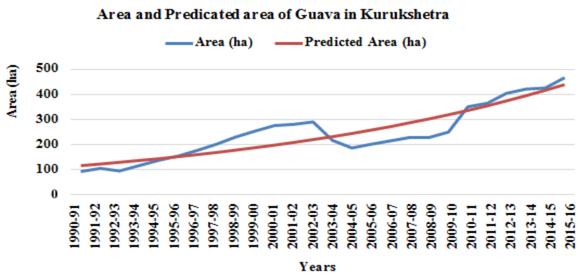

Fig. 3. *Actual and predicted value of area of Guava in Kurukshetra district for the year 1990-91 to 2015-16 through Logistic model.*

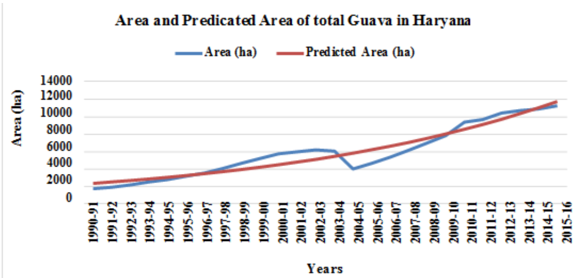

Fig. 4. *Showing the actual and predicted value of area of Haryana in Kurukshetra district for the year 1990-91 to 2015-16 through Logistic model.*

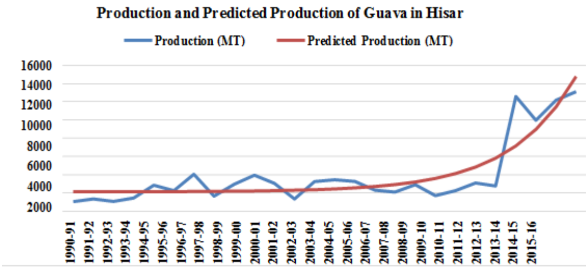

Fig. 5. *Actual and predicted value of production of Guava in Hisar district for the year 1990-91 to 2015-16 through monomolecular model .*

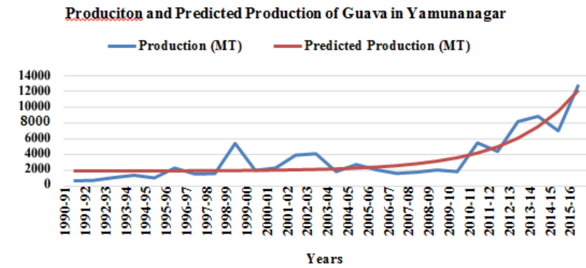

Fig. 6. *Actual and predicted value of production of Guava in Yamunanagar district for the year 1990-91 to 2015-16 through Monomolecular model.*

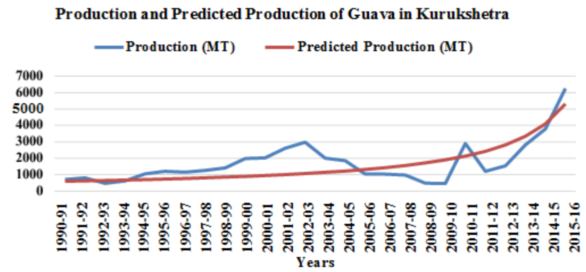

Fig. 7. *Actual and predicted value of production of Guava in Yamunanagar district for the year 1990-91 to 2015-16 through Logistic model.*

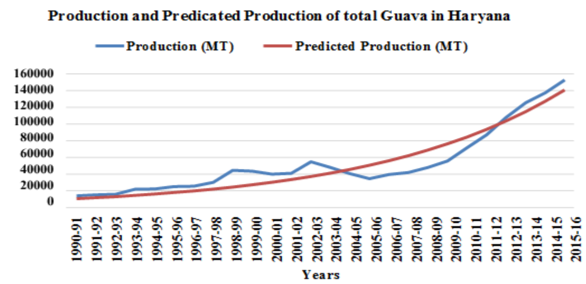

Fig. 8. *Actual and predicted value of production of Guava in Haryana State for the year 1990-91 to 2015 -16 through Logistic model.*

compound growth rates for area of guava during the time period 1990-91 to 2015-16 in Hisar, Yamunanagar, Kurukshetra district of Haryana and Haryana state as a whole. Since Logistic model was found to be the best fit model for the area of guava in Hisar, Kurukshetra district of Haryana and Haryana state as a whole the same was use to calculate the annual growth rate of in different district respectively. By taking mean value or average value of annual growth rate the average annual growth rate was found to be 8.48%, 5.17% and 6.47%.respectively. Whereas Gompertz model is used for computing calculating annual growth rate of Guava in Yamunanagar and it was observed that mean value or average value of annual growth rate was found to be 8.19%.

Table 4 shows the parameter estimation and selection criteria for the Hisar, Yamunanagar, Kurukshetra and Haryana state as a whole for different models i.e. Monomolecular, Logistic and Gompertz model for production of Guava from 1990-91 to 2015-16. From the above table it is concluded that monomolecular model has maximum value of R^2 and minimum value of MSE and RMSE for Hisar and Yamunanagar district. Therefore, monomolecular model found to be the best fit for computation of compound growth rates and predicted value for Hisar and Kurukshetra district. It is also observed from the table that logistic model found to be the best fit for Kurukshetra and Haryana state as a whole because of maximum value of R^2 and minimum value of MSE and RMSE and the same was used for computation of growth rate and predicted value of production of Guava in Kurukshetra and Haryana State as a whole. The figure number from5 to 8 shows the actual and predicted value of production of Guava for Hisar, Yamunanagar, Kurukshetra and Haryana state as a whole on the basis of best fitted model. Table 5 shows the predicted value and annual compound growth rates for production of guava during the time period 1990-91 to 2015-16 in Hisar, Yamunanagar, Kurukshetra district and Haryana as a whole state on the basis of best fitted model. It was observed from the table that average annual growth rate for production of guava was found to be7.93%, 7.62 %, 8.82 % and 10.20 % for Hisar, Yamunanagar, Kurukshetra district and Haryana as a whole state.

It is observed that Logistic model was the best fit for computation of growth rates of area for guava fruit in Hisar and Kurukshetra district and Haryana state as a whole whereas Gompertz model was best fit for Yamunanagar district based on high $R^2$and least MSE and RMSE values. It was also observed that monomolecular model was best fit for production of guava fruits in Hisar and Yamunanagar district whereas Logistic model was best fit for production of guava fruit in Kurukshetra and Haryana state as a whole because of high R^2 and least MSE and RMSE values. Mukherjee *et al.* (2016) studied the application of non linear growth model for estimation of annual compound growth rates of major pulses in Telangana state and observed that both the Logistic and the Gompertz model gave almost similar results. But in some cases the Logistic model proved to be better fit as compared to the Gompertz model. The estimated compound annual growth rates revealed that the area, production and yield of arhar has shown an increasing trend over the study period but there was a decreasing trend for moong in Telangana state.

Conclusion

Several packages like R, SAS and SPSS are readily available to fit the non linear growth model for computation of growth rates. In this paper R and excel software has been used for computation of average compound growth rate of guava fruit. The average annual growth rate for area of guava for Hisar, Kurukshetra, Yamunanagar district of Haryana and Haryana state as a whole was found to be 8.48%, 5.17% , 8.19% and 6.47% respectively, whereas the average annual growth rate for production of guava for the same was to be 7.93%, 7.62 %, 8.82 % and 10.20 % .

REFERENCES

1. Acharya, S.P., Basavaraja H., Kunnall, L.B., Mahajanashetti, S.B. and Bhat, A.R.S. (2012) Growth in area, production and productivity of major crops in Karnataka. *Karnataka J. Agric. Sci.,*25(4):431-436. https://DOI: 10.15740/HAS/AU/10.4/288-293
2. Anonymous (2015). Department of Horticulture, Government of Haryana. Retrieved from http://hortharyana.gov.in/en/statisticaldata.pdf
3. Draper, N. R. and H. Smith, (1998). Applied Regression Analysis, 3rd Edn., New York, USA: John Wiley & Sons.
4. Prajneshu, and Chandran, K.P. (2005). Computation of Compound Growth Rates in Agriculture: Revisited. *Agricultural Economics Research Review*, 18:317-324. https://*DOI*:10.5958/0974-0279.2019.00001.6
5. Rajarathinam, A., Parmar, R.S. & Vaishnav, P.R. (2010). Estimating Models for Area, Production and Productivity Trends of Tobacco (Nicotiana tabacum) Crop for Anand Region of Gujarat State. *Indian Journal of Applied Sciences*, 10:2419-2425. https://DOI;10.15373/2249555X
6. Singh, P.S.; Adarsha, L.K., Nandi; A.K. andJopir, O. (2018). Production Performance of Fresh Mango in India: A Growth and Variability Analysis. *International Journal of Pure Applied Biosciences,* 6(2):935- 941. https:// DOI: 10.18782/2320-7051
7. Singh, Rajender; Kumar, Manoj; Dahiya, Mamta and Baloda, Satpal (2019). Development of growth model for Ber powdery mildew in relation to weather parameters. *Indian Phytopathology.* pp1-7 72(1). https://*doi*.org/10.1038/164690b0
8. Kumar, Manoj; Battan, K.R. and Sheoran, O.P. (2019). Pre-harvest forecast model for rice yield using principal component regression based on biometrical character with R-software. *Int. J. Agricult. Stat. Sci.,15, (1): 323-326* https:// *doi*:10.1029/2008WR007163.
9. Mukherjee, Deep Naryana; Vasudev, N; Sushasini,K.; and Kumari, R. Vijaya (2016). Application of nonlinear growth models for estimation for annual compound growth rates of major pulse crops in the Telangana State.. *The J. Res. PJTSAU 44(1&2)27-33* https:// *doi*: 10.3389/fphys.2015.00119