Statistical Modeling on Area, Production and Productivity of Cotton (*Gossypium spp.)* Crop for Ahmedabad Region of Gujarat State

R.S. Parmar*, A. Rajarathinam, H.K. Patel and K.V. Patel

College of Agricultural Information Technology,
Anand Agricultural University, Anand -388 110, India.

(Received: 06 August 2015; accepted: 03 September 2015)

The present investigation was carried out to study area, production and productivity trends and growth rates of cotton crop grown in Ahmedabad Region of Gujarat State for the period 1949-50 to 2007-08 based on parametric and nonparametric regression models. In parametric models different linear, non-linear and time-series models were employed. The statistically most suited parametric models were selected on the basis of adjusted R^2, significant regression co-efficient and co-efficient of determination (R^2). Appropriate time-series models were fitted after judging the data for stationarity. The statistically sound model was selected on the basis of various goodness of fit criteria viz. Akaike's Information Criterion, Bayesian Information Criterion, RMSE, MAE and assumptions of normality and independence of residuals. In nonparametric regression optimum bandwidth was computed by cross-validation method. 'Epanechnikov-kernel' was used as the weight function. Nonparametric estimates of underlying growth function were computed at each and every time point. Residual analysis was carried out to test the randomness. Relative growth rates of area, production and productivity were estimated based on the best fitted trend function. None of the parametric model was found suitable to fit the trends in area, production and productivity of the cotton crop. Nonparametric regression was finally selected as the best fitted trend function for the area, production and productivity of cotton crop based on lower values of root mean square and mean absolute errors. Cotton production had increased at a rate of 2.58% which was due to combined effect of increase in area and productivity at a rate of 0.66 and 1.15 per cent per annum respectively.

Keywords: Adjusted R^2, stationarity, akaike's information criterion, bayesian information criterion, lijung and box test, cross validation, band width.

India is primarily an agriculture-based country and its economy largely depends on agriculture. About 25% of our country's Gross Domestic Product (GDP) comes from agricultural sector. Nearly 74 % of the country's population lives in villages and depends on agriculture. Therefore, country's development largely depends upon the development of agriculture (Nath, 2008). The middle Gujarat constitutes of eight different districts viz., Ahmedabad, Kheda, Anand, Vadodara, Mahisagar, Botad, Panchmahal and Dahod. Ahmedabad district covers an area of 7932.40 sq. km out of which 253900 ha is mainly area under cotton, paddy, wheat, bajra and castor crops. The information on crop area, production and productivity statistics are the backbone of agricultural statistical system. Regional data analysis is very vital since it forms the basis for economic and policy planning by the state and central governments. Hence, if a trend of the variability can be established by appropriate statistical methods, it will have practical utility. If any crop is showing decreasing trend in area, production and productivity, appropriate policy measures can be initiated if the corresponding data on trend are analyzed well in advance. Growth rate analyses are also widely employed to study the long-term trends in various agricultural crops (Panse, 1964).

* To whom all correspondence should be addressed.
E-mail: rsparmar@aau.in

The growth rates of different crops are estimated mostly through the parametric models by assuming the linear or exponential functional forms. A research workers (Panse, 1964; Dey, 1975; Reddy, 1978; Narain *et al.*, 1982; Patel *et al.*, 1986, Kumar and Rosegrant, 1994; Kumar, 1997; Borthakur and Bhattacharya, 1998; Joshi and Saxena, 2002; Singh and Srivastava, 2003; Shah *et al.*, 2005; Sarma, 2005; Patil *et al.*, 2009) have used parametric models, to estimate growth rates, which are currently being used by the planners or policy makers of the country. However, the data may not be following these linear or exponential models or may require fitting of higher degree polynomials or non-linear models. Further this models lack the econometric consideration i.e., normality and randomness of residuals. Under these circumstances it becomes imperative to take recourse to nonparametric regression approach, which is based on fewer assumptions.

The objective of the present study is to develop an appropriate statistical model to fit the trends and to calculate growth rates in area, production and productivity of cotton crop grown in Ahmedabad region of Gujarat state based on both parametric (Linear, non-linear and time-series) and nonparametric regression models.

MATERIALS AND METHODS

To achieve the stipulated objectives, the present study had been carried out on the basis of time-series data pertaining to the period 1949-50 to 2007-08 have been collected from various publication (Margdarshika, published yearly by Directorate of Agriculture) of Gujarat government (Anonymous, 2009).

In parametric models different linear (Montgomery *et al.*, 2003), non-linear (Ratkowsky, 1990; Bard, 1974; Draper and Smith, 1998) and Auto-Regressive Integrated Moving Average (ARIMA) time-series models (Box *et al.*, 1976) were employed. The statistically most suited parametric models were selected on the basis of adjusted R^2, significant regression co-efficient, co-efficient of determination (R^2), Root Mean Square Error (RMSE), Mean Absolute Error (MAE) and assumptions of residuals (normality and randomness).

Appropriate ARIMA models were fitted after judging the time-series data for stationarity based on visual inspection, auto-correlation function and partial auto-correlation function. The auto-correlation upto fifteen lags were worked out. The statistically most appropriate time-series model was selected based on various goodness of fit criteria viz. Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC), RMSE, MAE and assumptions of residuals (Shaprio-Wilk test for normality and Lijung & Box test for randomness).

In nonparametric regression (Hardle, 1990), the first step involved estimation of optimum bandwidth and was computed by cross-validation method. 'Epanechnikov-kernel' was used as the weight function. Nonparametric estimates of underlying growth function were computed at each time point. Residual analysis was carried out to test the randomness. A relative growth rate was calculated based on best fitted model.

RESULTS AND DISCUSSION

Different parametric (linear, non-linear and time series) and nonparametric regression models were fitted to study the trends in area, production and productivity data of the cotton crop. The characteristics of fitted linear, non-linear (Table 1, Table 2, Table 3) and time-series (Table 4) models are presented. The findings are discussed in sequence as under.

Trends in area, production and productivity based on parametric models

Among the fitted linear and non-linear models, for the area the Sinusoidal model with the maximum adjusted R^2 of 53 %, minimum values of RMSE (308.44) and MAE (229.17) (Table 1) ; for the production the third degree polynomial model with the maximum adjusted R^2 of 32 %, minimum values of RMSE (559.39) and MAE (416.60) (Table 2) ; for the productivity again the third degree polynomial model with the maximum adjusted R^2 of 35 %, minimum values of RMSE (49.97) and MAE (37.12) (Table 3) , respectively found suitable to fit the trends.

The Sinusoidal model fitted to the area, failed to the assumption of the residuals and hence none of the linear and non-linear models were found suitable to fit the trends in area. However, to fit the trends in production the third degree polynomial

Table 1. Characteristics of fitted linear and non-linear models for area of cotton crop

Model	Regression constant A	Partial regression co-efficient B	C	D	Goodness of fit R^2 / Adj.R^2	Shapiro – Wilks test	Run Test	RMSE	MAE
Linear	2040.63** (115.35)	-9.30** (3.34)	-	-	0.12** [0.10]	0.021	0.001	429.92	324.01
Quadratic	2004.11** (178.25)	-5.70 (13.71)	-0.06 (0.221)	-	0.12* [0.09]	0.026	0.001	429.64	326.70
Cubic	1154.31** (182.39)	157.44** (26.10)	-6.80** (1.01)	0.075** (0.011)	0.52** [0.50]	0.002	0.149	316.90	238.53
Exponential	1955.96** (176.63)	-0.005 (0.003)	-	-	0.06 [0.04]	0.030	0.001	436.82	337.24
Monomolecular	4207.74* (30608.49)	2177.41* (30474.11)	-0.00381* (0.0477)	-	0.12* [0.09]	0.000	0.000	429.83	324.77
Sinusoidal	1757.62* (42.51)	512.31* (62.96)	0.13* (0.006)	-2.20* (0.204)	0.55* [0.53]	0.002	0.695	308.44	229.71
Rational Function	265.71* (1044.00)	968.29* (1031.62)	0.292* (0.373)	0.070* (0.006)	0.34* [0.30]	0.002	0.000	373.20	278.01
Mod. Hoerl Model	5476.66* (1376.98)	0.102* (0.066)	-0.310* (0.069)	-	0.31* [0.29]	0.004	0.003	381.43	282.28
Hoerl Model	1336.41* (223.53)	0.981* (0.004)	0.268* (0.088)	-	0.27 [0.24]	0.007	0.000	391.64	305.20
Gompertz	1780.76* (60.36)	1.78* (3.21)	2.07* (2.97)	-	0.27 [0.24]	0.097	0.049	441.58	339.29

* Significant at 5% level
** Significant at 1% level
RMSE : Root Mean Square Error
MAE : Mean Absolute Error
Values in brackets ( ) indicate standard errors
Values in square brackets [ ] indicate Adjusted R^2

Table 2. Characteristics of fitted linear and non-linear models for production of cotton crop

Model	Regression constant A	Partial regression co-efficient			Goodness of fit				
		B	C	D Adj.R^2	R^2 / Adj.R^2	Shapiro –	Run Test	RMSE	MAE
Linear	1099.77** (175.54)	40.05** (5.09)	-	-	0.12** [0.10]	0.908	0.006	654.24	505.94
Quadratic	1207.18** (270.77)	3.48 (20.82)	0.18 (0.34)	-	0.12* [0.09]	0.858	0.001	652.64	506.08
Cubic	222.41 (321.95)	192.54** (46.08)	-7.64** (1.78)	0.087** (0.019)	0.36** [0.32]	0.202	0.897	559.39	416.60
Exponential	974.40** (173.24)	0.009 (0.005)	-	-	0.06 [0.04]	0.868	0.006	684.12	530.52
Monomolecular	33478.18* (3501776.67)	323279.75* (3501570.87)	0.000439* (0.0481)	-	0.12 [0.09]	0.000	0.000	654.29	505.98
Logistic	1639.89* (101.14)	3.24* (3.94)	0.310* (0.224)	-	0.15* [0.12]	0.249	0.049	643.07	477.00
Gompertz Relation	1640.43* (102.92)	0.551* (0.830)	0.254* (0.177)		0.15* [0.12]	0.284	0.049	643.57	478.43
Morgan-Mercer-Flodin	-73735.87* (45567898.12)	0.028* (17.51)	2483.07* (12518.49)	0.262 (5.40)	0.14* [0.09]	0.693	0.013	644.76	489.94

* Significant at 5% level; ** Significant at 1% level; RMSE : Root Mean Square Error
MAE : Mean Absolute Error; Values in brackets ( ) indicate standard errors; Values in square brackets [ ] indicate Adjusted R^2

Table 3. Characteristics of fitted linear and non-linear models for productivity of cotton crop

Model	Regression	Partial regression co-efficient			Goodness of fit				
	constant A	B	C	D Adj.R^2	R^2 / Wilks test	Shapiro –	Run Test	RMSE	MAE
Linear	82.23** (13.85)	2.17** (0.40)	-	-	0.34** [0.33]	0.908	0.006	51.62	38.88
Quadratic	89.47** (21.38)	1.46 (1.64)	0.012 (0.0266)	-	0.34** [0.32]	0.858	0.001	51.53	38.81
Cubic	52.68 (28.76)	8.52* (4.12)	-0.280 (0.159)	0.003 (0.002)	0.38** [0.35]	0.202	0.897	49.97	37.12
Exponential	83.48** (9.93)	0.015** (0.003)	-	-	0.25** [0.24]	0.868	0.006	52.72	42.21
Monomolecular	3661.05 (139683.51)	3579.18 (139667.26)	0.000617 (0.0245)	-	0.34* [0.32]	0.023	0.003	51.63	38.89
Logistic	-33.28* (378.72)	-1.34* (3.96)	0.003* (0.025)	-	0.35* [0.33]	0.104	0.013	51.38	38.87
Gompertz Relation	61322.68* (3711596.53)	1.88* (9.25)	0.002* (0.025)	-	0.34* [0.32]	0.116	0.088	51.49	38.76
Modified Horel Model	34.95* (14.92)	2.50* (2.09)	0.43* (0.113)	-	0.33* [0.31]	0.222	0.026	51.90	39.13

* Significant at 5% level; ** Significant at 1% level; RMSE : Root Mean Square Error
MAE : Mean Absolute Error; Values in brackets ( ) indicate standard errors; Values in square brackets [ ] indicate Adjusted R^2

Table 4. Characteristics of fitted time-series models for area, production and productivity of cotton crop

Aspects	ARIMA (p,d,q)	Constant	Auto-regressive Co-efficient ϕ_1	ϕ_2	ϕ_3	ϕ_4	ϕ_5	ϕ_6	AIC / BIC	Goodness of Fit: Shapiro – Wilks test	Box – Ljung	RMSE/ MAE
Area	(2,2,0)	-0.5884	-0.969 ***	-0.527 **	-	-	-	-	877.77 /	0.010	28.74	524.05 /
		(27.740)	(0.114)	(0.113)					883.89		[21.02]	360.38
	(3,2,0)	-2.459	-1.271 **	-1.088 **	-0.550 **	-	-	-	860.75 /	0.653	24.21	457.97 /
		(15.113)	(0.117)	(0.144)	(0.110)				868.92		[19.67]	336.75
Production	(2,2,0)	-2.664	-0.820 **	-0.294 **	-	-	-	-	943.68 /	0.316	18.45	928.11 /
		(58.467)	(0.130)	(0.130)					949.81		[21.02]	702.82
	(3,2,0)	-1.946	-0.931 **	-0.619 **	-0.396 **	-	-	-	936.05 /	0.197	11.31	859.41 /
		(39.074)	(0.125)	(0.158)	(0.127)				944.23		[19.67]	618.44
	(4,2,0)	-1.368	-1.049 **	-0.815 **	-0.701 **	-0.309 **	-	-	932.89 /	0.266	11.92	829.04 /
		(28.769)	(0.130)	(0.173)	(0.179)	(0.137)			943.11		[18.30]	590.73
	(5,2,0)	-0.024	-1.149 **	-1.030 **	-0.967 **	-0.670 **	-0.333 **	-	928.84 /	0.619	10.12	794.53 /
		(20.800)	(0.129)	(0.188)	(0.202)	(0.196)	(0.136)		941.10		[16.91]	587.60
	(6,2,0)	1.358	-1.243 **	-1.208 **	-1.217 **	-0.956 **	-0.669 **	-0.279 **	926.75 /	0.577	7.64	775.01 /
		(15.935)	(0.133)	(0.202)	(0.235)	(0.237)	(0.212)	(0.139)	941.06		[15.50]	569.92
Productivity	(2,2,0)	-0.026	-0.640 **	-0.282 **	-	-	-	-	666.59 /	0.091	27.18	81.61 /
		(5.665)	(0.131)	(0.130)					672.72		[21.02]	60.90
	(3,2,0)	-0.079	-0.775 **	-0.598 **	-0.488 **	-	-	-	653.02 /	0.355	9.25	71.75 /
		(3.362)	(0.118)	(0.136)	(0.119)				661.19		[19.67]	52.25
	(4,2,0)	0.027	-0.935 **	-0.798 **	-0.752 **	-0.321 **	-	-	649.15 /	0.489	10.91	68.71 /
		(2.430)	(0.129)	(0.154)	(0.156)	(0.135)			659.36		[18.30]	50.68
	(5,2,0)	0.145	-1.035 **	-1.024 **	-0.999 **	-0.617 **	-0.299 **		646.01 /	0.667	9.91	66.23 /
		(1.800)	(0.131)	(0.179)	(0.186)	(0.185)	(0.136)		658.27		[18.30]	49.08

RMSE : Root Mean Square Error
MAE : Mean Absolute Error
** the estimated t – values are greater than or equal to 2
Values in the brackets () are corresponding standard errors
Values in the square brackets [ ] indicate critical values for Chi – square statistic at 5 % level of significance

model was emerged as the best fitted models among the linear and non-linear models. In case of productivity , the partial regression co-efficient in linear term was significant and rest of the partial regression co-efficient were non-significant indicating that this fitted model failed to fulfill the model selection criteria and hence none of the linear and non-linear models were found suitable to fit the trends in productivity.

Trends in area, production and productivity based on time-series models

For the area, the stationarity was achieved by differencing two times i.e., d=2. The pattern of auto-correlations g_k showed damped sine-wave and significant partial auto-correlations f_{kk} at second and third lags. This suggested consideration of ARIMA (2,2,0) and ARIMA(3,2,0) as the candidate models and the results are given in Table 4. But since the Box-Ljung test values were significant in both the models, these models failed to fulfill the model selection criteria and hence none of the ARIMA families' of time-series models were found suitable to fit the trend in area under the cotton crop. However, the stationarity of production was achieved by differencing two times i.e., d=2. The pattern of auto-correlations g_k showed damped sine-wave and significant partial auto-correlations f_{kk} at second, third, fourth, fifth and sixth lags. This suggested consideration of ARIMA(2,2,0), ARIMA(3,2,0), ARIMA(4,2,0), ARIMA(5,2,0) and ARIMA(6,2,0) as the candidate models and the results are given in Table 4. But since the AIC (926.75), BIC(941.06), RMSE (775.01) and MAE (569.92) values were found to be lower than that of in the other candidate models, the ARIMA(6,2,0) was found suitable to fit the trend in production of cotton crop among the ARIMA families' of time-series models. In case of productivity the stationarity was achieved by differencing two times i.e., d=2. The pattern of auto-correlations g_k showed damped sine-wave and significant partial auto-correlations f_{kk} at second, third, fourth and fifth lags. This suggested consideration of ARIMA(2,2,0), ARIMA(3,2,0), ARIMA(4,2,0) and ARIMA(5,2,0) as the candidate models and the results are given in Table 4. But since the AIC (646.01), BIC(658.27), RMSE (66.23) and MAE (49.08) values were found to be lower than those in the other candidate models, the ARIMA(5,2,0) was found suitable to fit the trends in productivity of cotton crop among the ARIMA families' of time-series models.

Trends in area, production and productivity based on non-parametric models

Using the cross-validation method, for the area, production and productivity of the cotton crop, the optimum bandwidth was computed as 0.169, 0.203 and 0.054 respectively. Nonparametric estimates of underlying growth function were computed at each and every time point. Residual analysis showed that the assumptions of independence of errors were not violated at 5% level of significance. The RMSE, MAE values were for area 300.05 and 215.84; for production 547.87 and 397.52; for productivity 37.46 and 29.19 respectively. These values were much lower than those obtained through the parametric models, indicating thereby the superiority of this approach over the parametric approach. Nonparametric regression model was selected as the best fitted

Table 5. Period-wise relative growth rates of area, production and productivity of cotton crop

Period	Area (%)	Prod^{un} (%)	Prod^{ty} (%)
Ist Five Year Plan (1951-52 to 1955-56)	5.09	9.63	5.88
IInd Five Year Plan (1956-57 to 1960-61)	2.34	5.34	7.09
IIIrd Five Year Plan (1961-62 to 1965-66)	0.38	2.98	1.42
IVth Five Year Plan (1969-70 to 1973-74)	-1.69	-1.46	-0.61
Vth Five Year Plan (1974-75 to 1978-79)	-3.06	-3.72	-0.72
VIth Five Year Plan (1980-81 to 1984-85)	-3.84	-2.32	-1.87
VIIth Five Year Plan (1985-86 to 1989-90)	-1.02	2.43	7.89
VIIIth Five year Plan (1992-93 to 1996-97)	2.90	3.82	2.89
IXth Five Year Plan (1997-98 to 2001-2002)	1.81	3.12	-9.84
Xth Five Year Plan (2002-03 to 2006-2007)	1.36	3.69	11.01
Whole Period (1949-50 to 2007-08)	0.66	2.58	1.15

trend function for the area, production and productivity. The trend function indicates that there was an increasing trend upto 1965-66 and then the trend started to decline upto 1988-89 in area and production. It was found that there was a sudden shift in the trend and growth rate in the year 1989-80 for area (Fig.1) and production (Fig.2). The fitted trend for productivity is depicted in the Fig.3.

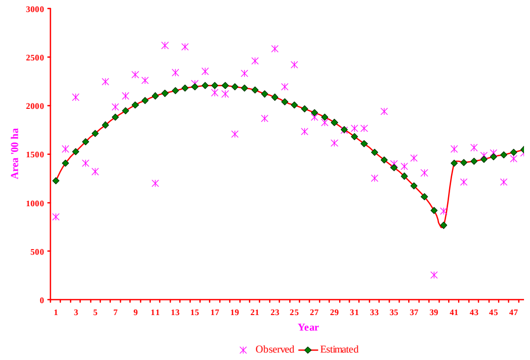

Fig. 1. Trends in area of cotton crop based on nonparametric regression with the jump points

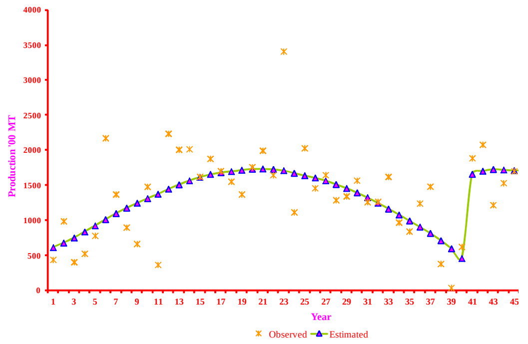

Fig. 2. Trends in production of cotton crop based on nonparametric regression with the jump points

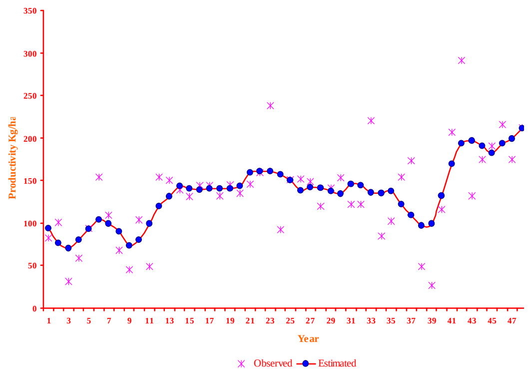

Fig. 3. Trends in productivity of cotton crop based on nonparametric regression

Discussion in area, production and productivity

Balanagammal *et.al.,* (2000) had reported ARIMA(1,0,0) model for area and productivity trend , ARIMA(0,0,0) model for production trend of cotton crop grown in Tamil Nadu. In the present study none of the family of ARIMA time-series models were found suitable due to nonsignificant auto-regressive co-efficients and lack of assumptions of normality of residuals. Nonparametric regression model was selected as the best fitted trend function for the area, production and productivity of cotton crop.

Growth rates in area, production and productivity

Relative growth rates of area, production and productivity of cotton crop were estimated for the successive years starting from 1949-50 to 2007-08 based on the best fitted growth function, the nonparametric regression model. Also the relative growth rate for each year for area, production and productivity were computed year-wise, for every fifth plan periods commencing from 1951-52 to 1955-56 and the average of five years period of each plan had been computed and given in Table 5. The per cent growth rate values obtained for the successive years during 1949-50 to 2007-08 for the area, production and productivity when averaged showed that the production had increased at a rate of 2.58 % which was due to combined effect of increase in area and productivity at a rate of 0.66 and 1.15 % per annum respectively (Table 5).

CONCLUSION

Nonparametric regression with jump-point emerged as the best fitted trend for the area, production of cotton crop. Significant jump-points were observed both in area and in production. It was found that a sudden shift in the trend and growth rate in the year 1989-90 for the area as well as in production of the cotton crop. These kind of changes can not be observed in the case of growth rate estimated using the traditional parametric approach. In case of productivity nonparametric regression without jump-point was selected as best fitted trend function. The per cent growth rate values obtained for the successive years during 1949-50 to 2007-08 for the area, production and productivity of cotton when averaged showed that 2.58 % increase in production which was due to combined effect of increase in area and productivity at a rate of 0.66 and 1.15 % per annum respectively.

REFERENCES

1. Anonymous. Districtwise area, production and yield per hectare of important food and non-food crops in Gujarat, Directorate of Agriculture, Gujarat, Krishi Bhavan, Gandhinagar, 2009.
2. Balanagammal, D., Ranganathan, C. R. and Sundareasan, R., Forecasting an agricultural scenario in Tamil Nadu. A time-series analysis. *J. Ind. Soc. Agril. Statist*., 2000; **53**(3):273–286.
3. Bard, Y., *Nonlinear Parameter Estimation*. Academic Press:New York, 1974.
4. Borthakur, S and Bhattacharya, B. K. Trend analysis of area, production and productivity of potato in Assam : 1951–1993. *Economic Affairs*, 1998; **43(**4): 221-226.
5. Box, G. E. P. and Jenkins, G. M., *Time Series Analysis : Forecasting and Control*, Second Edition, Holden Day, 1976.
6. Dey, A.K.. Rates of growth of agriculture and industry. Econ. Political Weekly, 1975; **10**: A26-A30.
7. Drapper, N. R. and Smith, H., *Applied Regression Analysis*, 3rd Edn., John and Wiley & Sons, USA, 1998.
8. Hardle, W., *Applied Non-parametric Regression*. Cambridge Univ. Press, 1990.
9. Joshi, P.K. and Saxena, R., A profile of pulses production in India: Facts, trends and opportunities. *Ind. J. Agric. Econ*., 2002; **57**:326-339.
10. Kumar, P. and Rosegrant, M.W., Productivity and sources of growth for rice in India. Econ. Political Weekly, 1994; **29**: 183-188.
11. Kumar, P., Food security: Supply and demand perspective. *Indian Farming*, 1997; **12**: 4-9.
12. Montgomery, D. C., Peck, E. A. and Vining, G. G., *Introduction to Linear Regression Analysis*. John Wiley & sons, Inc, 2003.
13. Narain, P., Pandey, R. K. and Sarup, S., Perspective plan for food grains. Commerce, 1982; **145**: 184-191.
14. Nath, S. K., *Manual on area and crop production statistics*. Central Statistical Organisation, 2008.
15. Panse, V. G., Yield trends of rice and wheat in first two five-year plans in India. *J. Ind. Soc. Agril. Statist*., 1964; **16**: 1–50.
16. Patel, R.H., Patel, G.N. and Patel, J.B., Trends and variability in area, production and productivity of Tobacco in India. *Ind. Tobacco J.*, 1986; **18**: 3-5.
17. Patil, B. N., Bhonde, S. R. and Khandikar, D. N., Trends in area, production and productivity of groundnut in Maharashtra. *Financing Agriculture*, 2009; 35-39.
18. Reddy, V. N., Growth rates. *Economic and Political weekly,* 1978; **13**: 806–812.
19. Ratkowsky, D. A., *Handbook of Non-linear Regression Models.* Marcel Dekker, New York, 1990.
20. Sarma, M., Study on agricultural growth performance of Assam. Economic. Affairs, 2005; **50**: 38-41.
21. Shah, A.N., Shah, H. and Akmal, N., Sunflower area and production variability in Pakistan: Opportunities and constraints. HELIA., 2005; **28**: 165-178.
22. Singh, A. and Srivastava, R.S.L., Growth and instability of sugarcane production in Uttar Pradesh: A regional study. *Ind. J. Agri. Econ.*, 2003; **58**:279-282.