

Statistical Investigation of Production Performance of Cumin in India

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ABSTRACT

Cumin is the dried, white fruit with greyish brown colour of a small slender annual herb. The surface of the fruit has 5 primary ridges, alternatively has 4 less distinct secondary ridges bearing numerous short hairs. The flowers are white or rose-colored in small umbels. By and large there has been considerable expansion in area and production of cumin in Gujarat, Rajasthan and whole India. Considering the productivity of cumin except Gujarat remaining state Rajasthan and whole India registered the negative growth rate. Moreover, in states and whole India different factors are influencing productivity of cumin; by and large nitrogen is the major factor to significantly effect on the cumin productivity. Also forecasting has been done using comparing ARIMA and GARCH model for year 2020. Globally seeing the cumin seed demand this forecasting can be used policy implications and future trend of production and productivity of cumin in India and major states. This helps shows that cumin production reached 375 and 562 '000 tonnes in year 2020 for Gujarat and whole India respectively.

Keywords: Trend analysis, factor of production, ARIMA, GARCH, forecasting

The major countries that produce *jeera* or cumin seeds are India, Turkey, Syria, Iran and China. India is the biggest producer of Cumin Seeds in global spice market and new crop of Indian Cumin Seeds start every year February, this year crop expected 3.30 thousand metric tons out of this more than 70% of the crop consumed by domestic & Globally exported, since next new crop – 2017 have to go long path of 8 months and this year price are already high than comparing to previous years (Spices board of India, 2017). Syria stands second in the list with a production figure of 25000 tons. This clears out the India is far more dominant in this context than any other country as it also possess the maximum area in the cultivation of the spice. Turkey and Iran have the same level of production i.e. 15000 to 20000 tons of cumin seeds and that makes them both stand third in the leading producer's list.

Though Syria, Turkey and Iran have a much lesser level of production as compared to India but these countries have an equally significant influence in the determination of world *jeera* prices. In India, the level of production and the total area under *jeera* cultivation has increased significantly during the last few years. Rajasthan is largest *jeera* producing state in the country. It contributed around 1.2 lakh tons in the country's total produce in the year 2003-04 and it also have the maximum area under *jeera* cultivation i.e. around 2.25 lakh hectares. Gujarat is the second largest cumin seed producer in India. Rajasthan and Gujarat contribute to approximately 90 per cent of the production in the India (CRN report, 2016). Cumin seeds contain numerous phyto-chemicals that are known to have antioxidant, carminative and anti-flatulent properties. The seeds are an excellent source of dietary fiber and also

contain certain health-benefiting essential oils such as *cuminaldehyde*. The active principles in the cumin may improve gut motility and help in digestion by augmenting gastro-intestinal enzyme secretions. The spice is an excellent source of minerals like iron, copper, calcium, potassium, manganese, selenium, zinc and magnesium. It also contains very good amounts of B-complex vitamins such as thiamine, vitamin B-6, niacin, riboflavin, and other vital antioxidant vitamins like vitamin E, vitamin A, and vitamin C. Mishra *et al.* (2017) studied the future trend of black pepper in India. Sahu and Mishra (2017) forecasted for total species for India and China using ARIMA model. In present Investigation the factors like fertilizers, environmental factors etc. affecting the production of cumin in India and its future performance using forecasting models.

MATERIALS AND METHODS

India is the largest producer and consumer of cumin in the world. Indian output is currently estimated to be around 445 thousand tonnes in the year of 2014. Gujarat and Rajasthan are the major production centers of cumin in the country contributing 99 percentage of total production. For our study data of cumin area, production and productivity from 1991-2000 to 2013-14 were collected and analysed.

Descriptive statistics

Descriptive statistics are used to summarize and describe data. Some measures that are commonly used to describe a data set are measures of central tendency and measures of variability or dispersion and measures of association. Measures of central tendency include the mean, median and mode, while measures of variability include the standard deviation (or variance), range, the minimum and maximum values of the variables, kurtosis, skewness, simple growth rate and compound growth rate.

Trend models

Trend models generally pictures the overall movement of any time series. For this study parametric models were explored to trace the trends of the production and trade behaviour (Borthakur and Bhattacharya, 1998) of cumin in India. The best fit models which are chosen for estimating the growth pattern is based on the R² values obtained.

The model with highest R² value is considered as the best model.

Regression analysis

For the purpose of present study, the following regression model will be assumed.

$$Y = f(RF, T_{max}, T_{min}, N, P, K)$$

where,

- Y = Cumin productivity (kg per hectare)
- RF = Rainfall (mm)
- T_{max} = Mean maximum temperature (°C)
- T_{min} = Mean minimum temperature (°C)
- N = Total nitrogen fertilizer consumption
- P = Total phosphorous fertilizer consumption
- K = Total potash fertilizer consumption

Autoregressive Integrated Moving Average (ARIMA) Model

The ARIMA methodology is also called as Box-Jenkins methodology. The emphasis of these methods is not on constructing single equation or simultaneous equation models but on analyzing the probabilistic or stochastic properties of economic time series on their own under the philosophy let the data speak for themselves and allow Y_t to be explained by past or lagged values of Y itself and stochastic error terms.

The Box-Jenkins methodology

Box-Jenkins methodology helps to find the values of p, d and q of an ARIMA model for a time series.

Autoregressive model

The notation AR (p) refers to the autoregressive model of order p. The AR(p) model is written:

$$X_t = c + \sum_{i=1}^p \rho_i X_{t-i} + \epsilon_t$$

where, ρ₁, ρ₂,..... ρ_p are the parameters of the model, c is a constant and ε_t is white noise. Sometimes the constant term is avoided.

Moving Average model

The notation MA (q) refers to the moving average series of order q:

$$X_t = \mu + \varepsilon_t + \sum_{i=1}^q \theta_i \varepsilon_{t-i}$$

Where the $\theta_1, \dots, \theta_q$ are the parameters of the model, μ is the expectation of X_t (often assumed to equal 0), and the $\varepsilon_t, \varepsilon_{t-1}, \dots$

GARCH (Generalized Autoregressive Conditional Heteroskedasticity)

Bollerslev (1986) proposed the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model in which conditional variance is also a linear function of its own lags and has the following form:

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \dots + \alpha_q \varepsilon_{t-q}^2 + \beta_1 h_{t-1} + \dots + \beta_p h_{t-p}$$

$$h_t = a_0 + \sum_{i=1}^q a_i \varepsilon_{t-i}^2 + \sum_{j=1}^p b_j h_{t-j} \quad \dots(1)$$

A sufficient condition for the conditional variance to be positive is,

$$a_0 > 0, a_i \geq 0, i = 1, 2, \dots, q; b_j \geq 0, j = 1, 2, \dots, p$$

The GARCH (p, q) process is weakly stationary if and only if $\sum_{i=1}^q a_i + \sum_{j=1}^p b_j < 1$. The most popular GARCH model in applications is the GARCH(1,1) model. The express GARCH model in terms of ARMA model, denote $\eta_t = \varepsilon_t^2 - h_t$. Then from eq. (1).

$$\varepsilon_t^2 = a_0 + \sum_{i=1}^{\text{Max}(p,q)} (a_i + b_j) \varepsilon_{t-i}^2 + \eta_t + \sum_{j=1}^p b_j \eta_{t-j} \quad \dots(2)$$

Thus, a GARCH model can be regarded as an extension of the ARMA approach to squared series $\{\varepsilon_t^2\}$.

RESULTS AND DISCUSSION

Per se performance of cumin production in India

Per se performance of cumin is presented in Table 1. From the table, one can find that in India, the area of cumin cultivation increased from 73.60 thousand hectares (1991) to 858.90 thousand hectares (2014) with an average area of 321.88 thousand hectares

with registered simple growth rate of India is 14.96 over the study period. Leptokurtic and positively skewed nature of Gujarat, Rajasthan and whole India indicates that the steady improvement in area during the early period under consideration and remain almost same in later half. Considering the states, Gujarat regarded highest average area (236.28 thousand hectares) of cumin followed by Rajasthan (221.83 thousand hectares) with registered simple growth rate of 4.25 percent for Gujarat and 4.80 percent for Rajasthan.

Cumin production in India has increased from 28.20 thousand tonnes (1991) to 513.90 thousand tonnes (2014) during the study period and has registered a simple growth rate of 41.90 percent per annum. In case of Gujarat production has increased from 28.80 thousand tonnes to 283 thousand tonnes and registered growth rate of 23.74 percent. Considering Rajasthan, the production has increased from 23.67 thousand tonnes to 178 thousand tonnes and with simple growth rate of 18.77 percent. Both states and whole India, positive skewness and kurtosis indicates that the maximum growth has taken place during the early period under study and remained almost same in the latter half. In India, cumin with an average productivity of 413.34 kg/ha and productivity varied from 330 kg per hectare (1991) to 498.67 kg per hectare (2014) with the registered simple growth rate of -0.01 percent. Gujarat (an average productivity of 469.36 kg/ha and productivity varied from 303.01 kg per hectare to 589.64 kg per hectare) is the best state followed by Rajasthan (an average productivity of 351.76 kg/ha and productivity varied from 219.42 to 531.02 kg/ha) with simple growth rate of 3.58 percent (Gujarat) and -1.34 percent (Rajasthan) respectively. In Gujarat, the negative value of kurtosis (-1.34) and skewness (-0.34) indicates that there has been marginal shift of productivity under cumin during recent year under study. Both Rajasthan and whole India, platykurtic and negative skewness (-0.01) reveals that steady improvement in productivity during the early period under study and remain almost same in later half.

From the table it is clear that Gujarat is the single largest producer of cumin in the country accounting for 60 per cent of total production and the rest of the output comes from Rajasthan. Gujarat and Rajasthan together account for about 99 per cent

Table 1: Per se performance of cumin production in major states of India during 1991- 2014

	Area ('000 ha)			Production ('000 t)			Productivity (kg/ha)		
	Gujarat	Rajasthan	India	Gujarat	Rajasthan	India	Gujarat	Rajasthan	India
Mean	236.28	221.83	321.88	110.25	75.87	182.28	469.36	351.76	413.34
SE	12.87	14.19	33.92	16.72	8.92	25.98	19.04	16.13	7.19
Kurtosis	0.78	-0.84	-0.03	0.27	0.11	-0.30	-1.34	-0.24	-0.52
Skewness	1.14	0.58	0.82	1.19	1.00	1.13	-0.34	0.44	0.19
Minimum	149.60	135.11	73.60	28.80	23.67	28.20	303.01	219.42	330.00
Maximum	374.00	368.00	858.90	283.00	178.00	513.90	589.64	531.02	498.67
SGR %	4.25	4.80	14.96	23.74	18.77	41.90	3.58	-1.34	-0.01
CGR %	2.97	3.25	6.05	8.25	7.36	7.59	2.62	-1.61	-0.01

Table 2: Trends in area, production and productivity of cumin in major states of India

States	Equation	Area ('000 ha)								
		Model Summary						Parameter Estimates		
		R ²	F	df1	df2	Sig.	Const.	b1	b2	b3
Gujarat	Quadratic	0.91	52.29	2	21	0.00	201	-5.81* (3.31)	0.530** (0.12)	
Rajasthan	Cubic	0.59	3.47	3	20	0.03	104	49.41* (19.75)	-5.04* (1.81)	0.140** (0.04)
India	Linear	0.66	17.48	1	22	0.00	77	8.44** (2.02)		
States	Equation	Production ('000 tonnes)								
		Model Summary						Parameter Estimates		
		R ²	F	df1	df2	Sig.	Const.	b1	b2	b3
Gujarat	Quadratic	0.96	163.44	2	21	0.00	66	-8.97** (2.59)	0.766** (0.10)	
Rajasthan	Cubic	0.63	4.40	3	20	0.01	11	21.79* (11.88)	-2.220** (1.09)	0.06* (0.02)
India	Linear	0.57	10.55	1	22	0.04	44	2.83** (0.873)		
States	Equation	Productivity (kg/ha)								
		Model Summary						Parameter Estimates		
		R ²	F	df1	df2	Sig.	Const.	b1	b2	b3
Gujarat	Linear	0.79	36.89	1	22	0.00	339	10.45** (1.72)		
Rajasthan	Linear	0.52	8.05	1	22	0.01	424	-6.46* (2.28)		
India	Linear	0.68	32.37	1	37	0.00	331	2.98** (0.52)		

Note: ** significant at 1%; * significant at 5%; figures in the parenthesis indicates Standard Error; df1: Regression degrees of freedom; df2: Residual degrees of freedom.

of cumin production in the country. Both Gujarat and Rajasthan used to produce almost equal amount output until the early 2000s. But output from Gujarat increased rather steeply from year 2001 onwards and became the single largest producer. Though, Negative growth rate of cumin productivity in Rajasthan is the reason behind it's number two position in the cumin production. Unseasonal rainfall at the time flowering is likely to affects the productivity of Rajasthan. Research on development of off season cumin varieties may sustain the productivity of cumin in Rajasthan.

Trend analysis of area, production and productivity of cumin

Knowing the above overall performance, path of movement of the series was traced through parametric trends models. To workout the trends in area, production and yield of cumin different parametric model like polynomial, logarithmic, compound, growth, and exponential models as discussed in material and method section are attempted too. Among the competitive models the best model is selected on the basis of the maximum R² value, significance of the model and

its coefficients. The following section presents the results of this exercise (Table 2).

In all data series of area, production and productivity of cumin in major states and whole India, non-linear patterns are revealed (Fig. 1.A, B and C) that, area and production series of Gujarat and Rajasthan fitted well with quadratic model and cubic model respectively. Productivity of both states and all data series of whole India follow the linear trend. Positive nature of third coefficient indicates increasing in recent past in area and production of cumin in Rajasthan. Linear trend in productivity indicates that there is no change in productivity of cumin over the study period.

Thus from the test of trend analysis of area, production and productivity of cumin in major states of India the following important features has emerges out. All data series of cumin production follows the definite pattern of trend. Rajasthan shows increasing trend in area and production series. Trend in area and production of cumin in Gujarat and Rajasthan shows the increased in nature, visualized by positive b2 coefficient in Gujarat and b3 coefficient in Rajasthan. The increased trend shows interest of farmers to grow cumin; whereas productivity of cumin fitted with

linear trend, almost straight line in entire study period. So meet the global need necessary actions are required to increase the production of cumin.

Regression analysis of factor affecting the productivity of cumin in major states of India

In order to find out the relationship of productivity with climatological and nutrients factors multiple linear regression equations are fitted. The most important factors influencing cumin productivity in major states is identified by using step-down regression analysis (Table 3). A significant coefficient of nitrogen factor on productivity of cumin noticed in Gujarat and Rajasthan. A unit change in nitrogen fertilizer would lead to an increase in productivity of cumin by 0.27 kg per hectare in Gujarat and decrease in productivity by 0.204 kg per hectare in Rajasthan respectively. Similarly, in whole India potassium fertilizer and T_{min} had significant coefficient on cumin productivity. Thus, one unit change in potassium fertilizer and T_{min} would lead to increase in productivity of cumin by 0.016 kg per hectare and 29.205 kg per hectare respectively. From the above table it is clearly visible that not all factors are equally effective on productivity of cumin. Moreover, in states and whole India different

Table 3: Regression analysis of factor affecting the productivity of cumin in major states of India

		Gujarat				
Model		B	SE	Sig.	R ²	Adj. R ²
A	(Constant)	106.257	1535.453	0.946	0.62	0.48
	N	0.447	0.202	0.041		
	P	-1.533	0.916	0.112		
	K	2.462	1.53	0.126		
	RF	0.036	0.063	0.572		
	T_{max}	-13.981	40.267	0.733		
B	T_{min}	34.316	43.218	0.438	0.54	0.52
	(Constant)	280.125	39.224	0.000		
	N	0.27	0.053	0.000		
		Rajasthan				
Model		B	SE	Sig.	R ²	Adj. R ²
A	(Constant)	-1810.24	5224.427	0.733	0.523	0.484
	N	-0.178	0.242	0.472		
	P	-0.067	0.492	0.893		
	K	0.055	0.959	0.955		
	RF	-0.081	0.16	0.618		
	T_{max}	187.905	401.57	0.646		
B	T_{min}	-202.172	422.719	0.639	0.473	0.424
	(Constant)	454.97	38.61	0.000		
	N	-0.204	0.071	0.009		

		India				
Model		B	SE	Sig.	R ²	Adj. R ²
A	(Constant)	299.318	437.853	0.498	0.697	0.586
	N	0.007	0.007	0.325		
	P	-0.048	0.024	0.053		
	K	0.084	0.034	0.019		
	RF	0.092	0.065	0.164		
	T _{max}	-39.895	25.443	0.125		
	T _{min}	73.79	30.939	0.022		
B	(Constant)	-109.571	267.617	0.684	0.593	0.554
	K	0.016	0.007	0.027		
	T _{min}	29.205	15.69	0.070		

Note: A is full model; B is step-down regression model.

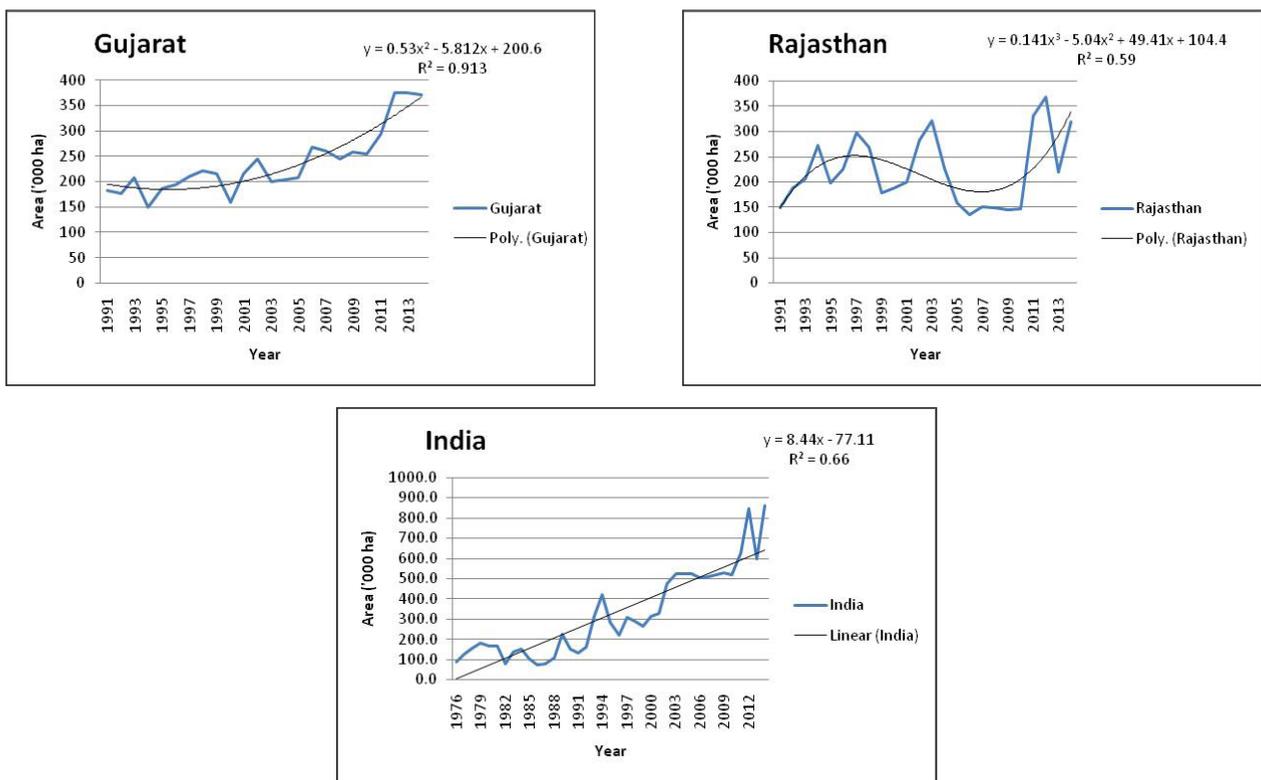


Fig. 1A: Observed and expected trends of area under cumin in major states of India

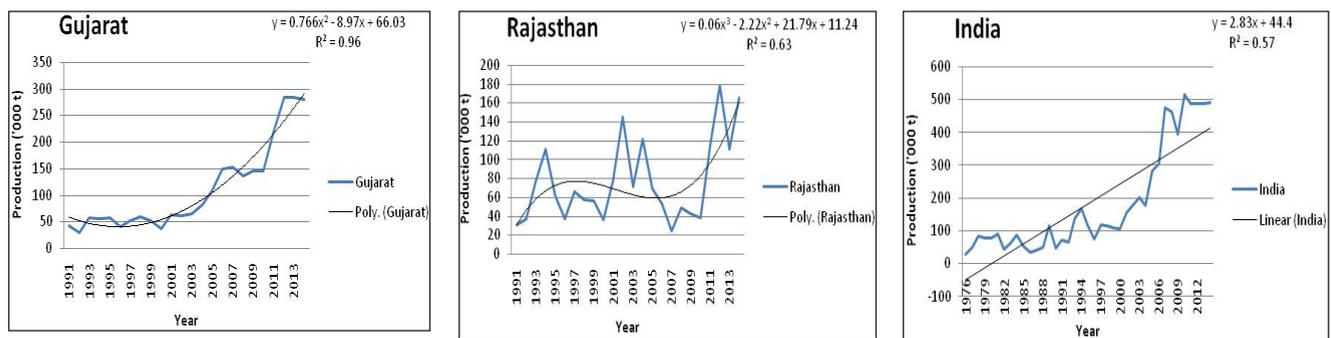


Fig. 1B: Observed and expected trends of production under cumin in major states of India

Table 4: Best fitted ARIMA and GARCH models for area under cumin in India

State	Model	Model Selection Criteria								
		AIC	BIC	ME	RMSE	MAE	MPE	MAPE	MASE	R ²
<i>Area (000'ha)</i>										
Gujarat	ARIMA(1,2,1)* No GARCH	212.51	213.55	8.69	35.51	26.69	1.91	12.24	0.95	0.51
Rajasthan	ARIMA(1,1,2)* GARCH (1,2)	244.08 278.95	247.36 287.19	1.51 2.44	53.34 57.36	44.96 52.17	-5.58 -3.53	21.42 24.21	0.95 1.75	0.58 0.52
India	ARIMA(1,1,2)* No GARCH	445.83	453.74	0.35	20.72	19.42	-11.71	5.42	0.96	0.85
<i>Production ('000 tonnes)</i>										
Gujarat	ARIMA(1,1,1)* No GARCH	197.81	199.00	0.00	23.86	18.11	-11.39	24.59	0.97	0.88
Rajasthan	ARIMA(1,1,2)* GARCH (1,2)	226.16 254.24	230.10 262.49	0.45 0.78	36.43 39.25	30.27 31.40	-26.00 -19.49	50.78 50.78	0.88 1.23	0.61 0.49
India	ARIMA(1,2,1)* No GARCH	405.62	408.89	0.00	47.11	33.38	-11.62	29.15	0.99	0.91
<i>Productivity (Kg/Ha)</i>										
Gujarat	ARIMA(1,1,1) GARCH (1)*	243.50 239.43	244.55 241.32	11.92 9.88	74.28 71.24	52.56 41.41	1.29 0.99	12.15 10.31	0.95 0.79	0.58 0.57
Rajasthan	ARIMA(0,2,1)* GARCH (1)	251.91 279.32	253.05 285.21	-5.48 -4.87	54.20 57.74	40.60 56.01	-2.83 -1.00	12.02 17.62	0.96 1.57	0.68 0.53
India	ARIMA(2,1,1)* GARCH (1,2)	375.66 447.18	382.31 459.83	-0.33 0.47	26.53 28.78	21.39 23.25	-0.51 -1.23	5.28 5.77	0.77 0.98	0.64 0.54

Note: * indicates the best model and used further for forecasting purpose.

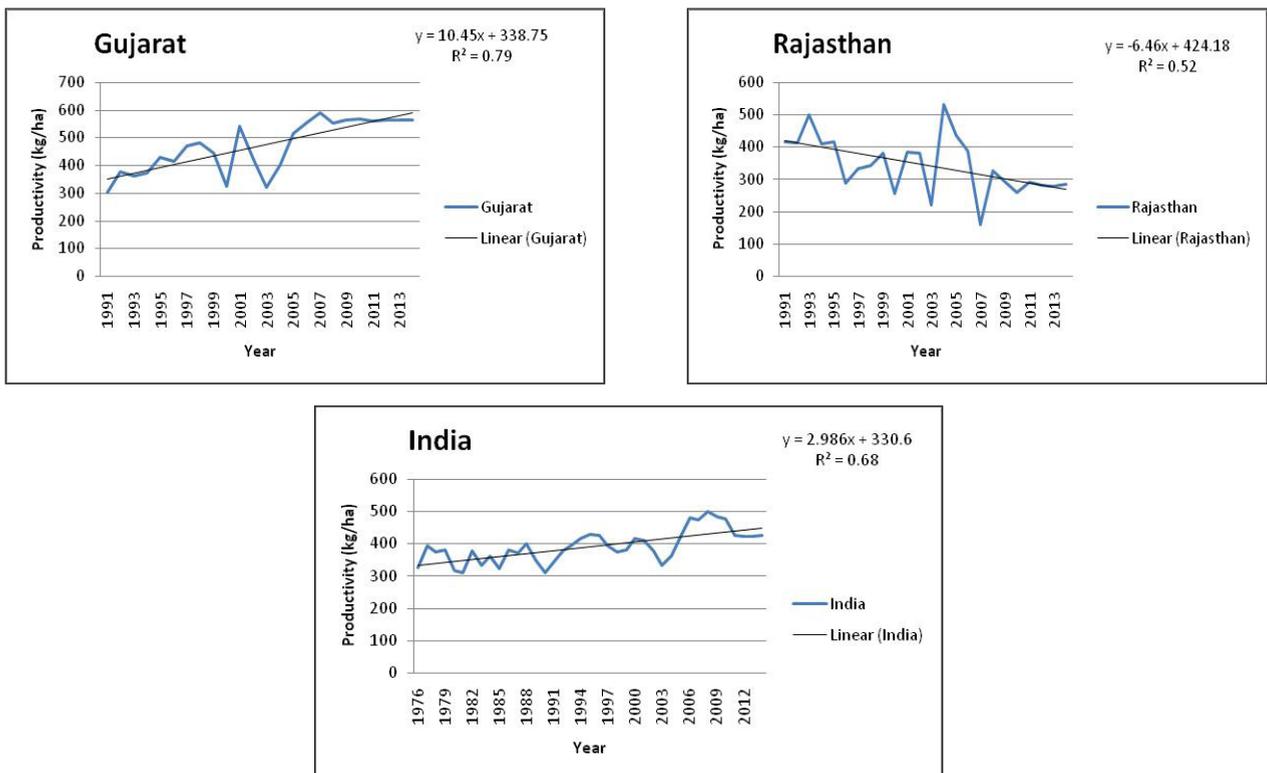

Fig. 1C: Observed and expected trends of productivity under cumin in major states of India

Table 5: Validation and forecasting of area under cumin in India on the basis of selected best model

State	Model	2012		2013		2014		2016	2018	2020
		Observed	Predicted	Observed	Predicted	Observed	Predicted	Predicted	Predicted	Predicted
<i>Area ('000 ha)</i>										
Gujarat	ARIMA(1,2,1)	374	379	374	374	370	377	368	372	381
Rajasthan	ARIMA(1,1,2)	368	318	220	252	220	217	223	205	234
India	ARIMA(1,1,2)	843	757	794	742	759	786	808	843	878
<i>Production ('000 tonnes)</i>										
Gujarat	ARIMA(1,1,1)	283	230	283	294	280	306	329	352	375
Rajasthan	ARIMA(1,1,2)	178	158	111	107	165	132	144	143	143
India	ARIMA(1,2,1)	486	498	486	498	489	498	513	538	562
<i>Productivity (Kg/Ha)</i>										
Gujarat	GARCH (1)	565	561	565	565	564	565	565	565	565
Rajasthan	ARIMA(0,2,1)	280	286	276	278	283	279	283	283	283
India	ARIMA(2,1,1)	422	392	421	418	423	418	416	413	414

factors are influencing productivity of cumin; by and large nitrogen is the major factor to significantly effect on the cumin productivity.

Modeling and Forecasting

From Table 4, shows the comparison between the GARCH and ARIMA model and used for forecasting purpose up to 2020. Best of ARIMA and GARCH models are selected based on the minimum value AIC, BIC, ME, RMSE, MAE, MPE, MAPE and maximum value of R². The selected models are also validated for accuracy by using last three years data and observed that the actual and predicted values are in range (Table 5). From the table it is clear that ARIMA(1,2,1) for Gujarat, ARIMA(1,1,2) for Rajasthan and whole India are found to be best ARIMA model for modeling area of cumin cultivation. Similarly among the various GARCH models, GARCH(1,2) for Rajasthan was best fitted GARCH models, whereas data series of area under cumin in Gujarat and whole India is found not to have GARCH effect. From the Table 4, it is clear that ARIMA(1,2,1), ARIMA(1,1,1) and ARIMA(1,1,2) are found to be best ARIMA models for modeling cumin production in Gujarat, Rajasthan and whole India respectively. In the same way, among the various GARCH models, GARCH(1,2) for Rajasthan was best fitted GARCH model, whereas data series of cumin production in Gujarat and whole India are found not to have GARCH models. For modeling cumin productivity in Rajasthan and whole India

ARIMA models are found to be better than GARCH. Considering Gujarat data series, GARCH(1) model is found to be the best fitted.. Rajasthan shows no improvement, future year value remains same as base year 2014 value and whole India shows declined value for future 2020 as compared to base year 2014.

CONCLUSION

Thus, from the study of *per se* performance of area, production and productivity of cumin the following salient features are emerge out. Gujarat is highest contributor of cumin followed by Rajasthan in India. Considering the annual growth rate the state Rajasthan registered highest in case of area and production. Gujarat registered highest annual growth rate in case of productivity. Cumin, ARIMA model fitted well most compare to GARCH model. On the basis of forecasted value, area of cumin, whole India will be reached 878 '000 ha in year 2020. In production Forecasted value shows increased trend in productivity as compared to the base year in the state of Gujarat. The state Gujarat indicates there would be marginal improvement in cumin productivity for 2020. Appropriate policies and high yielding varieties, resistant to adverse environmental condition varieties are required to increase the cumin productivity.

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