



A Comparative Growth Trend Study of Tomato in Jaipur and Sirohi District of Rajasthan, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Tomato (*Lycopersicon esculentum*) is an important crop that contributes economically and significantly to horticulture production. The study was conducted for the period of 12 year in Jaipur and Sirohi districts of Rajasthan to analyze the growth rate in area, production, and productivity from 2010-11 to 2021-22. (Department of Horticulture, Government of Rajasthan-2022-23). For analyzing the trend in area production and productivity of tomatoes in Jaipur and Sirohi district, and Rajasthan state the following linear, semi-log, and exponential functions were tested. The tested model were selected based on high R^2 (Coefficient of determination) and the best-fit function was used for the result discussion. Semi-log function was best function for the area,

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production and productivity of Rajasthan. The compound annual growth rate (CAGR) for area of Rajasthan was found 1.76 percent, with 0.46 R². The production and productivity show 9.91 and 8.15 percent growth rate. The semi-log function was also best fit the area and production of Tomato in Jaipur district with 4.58 and 15.94 percent annual growth respectively. The linear function was fitted for the productivity that shows 17.20 percent CAGR with 0.39 percent R². The area of tomato in Sirohi district shows highest fluctuation due to this an exponential function was shows poor fits for calculate the growth rate this function shows 0.01 percent compound annual growth rate. The exponential function was best fit for the production and productivity with 0.41 and 0.31 R² respectively. The exponential function show 11.24 percent growth rate, which was significant at 5 percent level. The productivity show 12.25 percent compound annual growth rate with 10 percent level of significance. Thus the productivity shows highest compound annual growth rate followed by Production and area in Jaipur and Sirohi district of Rajasthan, while in Rajasthan, production shows highest growth rate followed by productivity and area. According to the findings, the result suggest for the introduction of high yield varieties of tomato may increase the productivity in Rajasthan.

Keywords: Tomato; semi-log; CAGR; area; production and productivity.

1. INTRODUCTION

Tomato an economically important crop contributes significantly to horticulture production (Ghalawat et al., 2024). More than 40 kinds of vegetables from different groups are grown in India. Tomato, onion, brinjal, cabbage, cauliflower, okra, and peas are among the most important vegetables grown in India (Tegar et al., 2016). Tomatoes, onions, and potatoes, popularly known as the TOP vegetables, are the three largest cultivated, produced and consumed vegetables in India. Vegetables are excellent source of vitamins, particularly niacin, thiamin, riboflavin and vitamins A and C. They also supply minerals such as iron and calcium besides proteins and carbohydrates (Agriculture and Processed Food Products Export Development Authority (APEDA); 2022, Shreyanaet al., 2022, Singh et al., 2023). For tomatoes, a well-known Indian saying is "No tomato, no cooking" but 99% of the tomatoes are currently consumed fresh as it is currently estimated that only about 150,000 tonnes of tomatoes are processed annually (Laxkar et al., 2022). In 2021-22, approximately 20300.19 tons of tomatoes were produced in 840 thousand hectares in the country making up almost 9.63 percent of the total vegetable production (Ghalawat et al., 2024). India has 2nd rank in both area and production of tomatoes worldwide after China (Harisha et al., 2019, Gupta et al., 2021). Despite its high production in India, the average productivity level remains low as compared to other tomato-producing countries (Ghalawat et al., 2024). Tomato is growing year-round as per the weather suitability in different country locations. It has the advantage of both domestic consumption and international demand (Anamika et al., 2023).

In recent decades, India has witnessed considerable growth in the production and productivity of tomatoes. Growth in the horticultural area was highest in the year 2003-04 which is about 18.1 per cent; while production growth was highest in 2007-08 about 10.1 per cent. Highest productivity was in the year 2009-10 which was 10.7 metric tons/ha while the lowest is 8.0 metric tons/ha in 2003-04 (Nabi and Bagalkoti, 2017). This growing trend has been influenced by various factors such as technological advancements, improved farming practices, changing market dynamics, climate change, government policies, and increasing demand globally (Ghalawat et al., 2024). During the year 2022-23, total vegetable output in Rajasthan was 2334884 MT in 192712 hectare area. Rajasthan has 20622 hectares area under tomato cultivation which contributes 10.70 percent of total vegetable cultivation. The total tomato output in Rajasthan was 255992 MT which contributes 10.96 percent of total vegetable output. During the year 2022-23, Jaipur stands on first position in tomato-producing districts in Rajasthan followed by Sirohi and Sikar. Jaipur district has a 13870-hectare area under tomato cultivation with 185477 MT production, which contributes 67.26 percent of the total tomato cultivated area and 72.45 percent total tomato production of Rajasthan respectively. With the 27335 MT production Sirohi district is the second-largest in tomato production and first largest in productivity of tomato in Rajasthan. Sirohi has 1287 hectare area under tomato cultivation, which contributes 6.24 percent of the total tomato cultivated area under Rajasthan and it contributes 10.67 percent of the total tomato production of Rajasthan (Department of

Horticulture, Government of Rajasthan; 2022-23).

2. METHODOLOGY

The study was conducted in the Jaipur and Sirohi districts of Rajasthan to analyze the growth rate in area, production, and productivity during the 12 years from 2010-11 to 2021-22. The research used statistical tools and quantitative analyses to extract insights from time series secondary data acquired from Rajasthan's horticulture department. For analyzing the trend in area production and productivity of tomatoes in Jaipur and Sirohi district, and Rajasthan state the following linear, semi-log, and exponential functions were tested. Based on high R² (Coefficient of determination) the best-fit function was used for the result discussion [2,5].

Linear Function:

$$Y = \alpha + \beta t$$

Where,

Y = Area/production/productivity of tomato

α = Constant

β = Coefficient factor

t = Year factor

The annual linear growth rate by linear function was computed as follows

$$r = \frac{\beta_1}{\bar{y}} \times 100$$

Semi log function:

$$\text{Log } Y = \alpha + \beta t$$

Where,

Y = Area/production/productivity of tomato

α = Constant

β = Regression coefficient

t = time in the year

To obtain the annual semi-log growth rate, it was computed as follows as

$$r = (\beta_1 * 100)$$

Exponential function

$$Y = \alpha \beta^t$$

Taking both side logs for linear transformation of this functional model.

$$\text{Log } Y = \log \alpha + t \log \beta$$

$$Y^* = \alpha^* + \beta^* t$$

Where,

$$Y^* = \log Y$$

$$\alpha^* = \log \alpha$$

$$\beta^* = \log \beta$$

Where,

Y = Area/production/productivity of tomato

α = Constant

β = Regression coefficient

t = time in the year

The annual Exponential growth rate was then computed as $r = (e^{\beta^*} - 1) \times 100$

e = Euler's exponential constant (=2.71828) (Sawant, 1983)

3. RESULTS

3.1 Growth Rate in Area, Production, and Productivity of Tomato in Rajasthan State

As mentioned in the methodology, to calculate the growth rate in area, production, and productivity, all the growth given functions were tested as given in Table 1. Based on the function section criteria the semi-log function best fits at 1 percent level of significance for the area of Rajasthan with the highest 0.46 percent coefficient of determination (R²) and minimum Root Mean Square Error (0.0722). By using this function the growth rate of the area of Rajasthan shows 1.76 percent compound annual growth during the 12 years from 2010-11 to 2021-22. By using this semi-log function, the predicted area of Rajasthan for the year 2023-24 was obtained at

20292.37 hectares and it was 20622 hectares for the same year on actual. For the growth rate in the production and productivity of Rajasthan, the semi-log function was the best fit at 1 percent level of significance, which shows 0.68 and 0.60 percent R². By this function, production shows a 9.91 compound annual growth rate and productivity shows an 8.15 percent compound annual growth rate in the study period. The RMSE for the production and productivity was 0.2533 and 0.2487 respectively. The predicted value for the production of tomatoes for the year 2022-23 was 182956 MT and it was 255992 MT in actual. The predicted value for the productivity of tomatoes for the year 2023-24 was 9043.49 quintal and it was 12413.53 MT in actual. Shreyana et al. 2022 studied for the period 2000-01 to 2009-10 which show negative growth rate in area, production and productivity by 0.13, 1.01 and 0.87 respectively. Ghalawat et al. [1], find that the area under tomato registered an increase by 3.98 per cent per annum during 2001-02 to 2021-22).

Laxkar et al. [6] studied on growth rate in area production and productivity for the Madhya Pradesh (MP) and Andhra Pradesh (AP) for the 10 year period form 2010-11 to 2020-21. The finding was that the MP's area, production and productivity show positive growth rate with 7.85, 12.72 and 4.51 percent CGR respectively, while AP's area and production shows negative growth rate by 19.23 and 9.22 percent CGR and productivity show positive growth rate by 12.40 percent CGR.

3.2 The Growth Rate in area, Production, and Productivity of Tomatoes in the Jaipur District of Rajasthan

Table 2 shows the all three tested function for calculate the growth rate in area, production and productivity in Jaipur district of Rajasthan. The semi-log function was best fits for the area and

production of Jaipur district with highest 0.86 and 0.46 R² and lowest, 0.067 and 0.646 Root Mean Square Error respectively with 1 percent significant level. The semi-log function shows 4.58 and 15.94 percent compound annual growth rate in area and production in Jaipur district during the 12 year period. For calculate the productivity of Jaipur district, linear function was best fits at 5 percent level of significance.

The linear function shows 0.39 percent R² and that shows 17.20 percent compound annual growth rate in productivity of Jaipur district (Singh et al. 2023 find that, In India, the compound annual growth rate of productivity under tomato cultivation was 1.90 percent). By using the semi-log function, the predicted value of area for the year 2022-23 was 12581.72 hectare and it is in actual 13870.00 hectare but due to low R² for the production and productivity, the predicted value shows more variation form actual value. The production of Rajasthan and Jaipur district tomato suddenly got increase during the year 2019-20 to 2020-21, due to an increase in the area in the same period.

3.3 The Growth Rate in Area, Production, and Productivity of Tomatoes in the Sirohi District of Rajasthan

Table 3 shows about the all three tested function for calculate the growth rate in area, production, and productivity in the Sirohi district of Rajasthan. It was found that the area of tomatoes in the Sirohi district shows the highest fluctuation due to this an exponential function shows poor fits for calculating the growth rate this function shows a 0.01 percent compound annual growth rate. The exponential function was best fit for the production and productivity with 0.41 and 0.31 R² respectively. The exponential function shows an 11.24 percent growth rate, which was significant at the 5 percent level.

Table 1. Growth rate in area, production, and productivity of tomato in Rajasthan State (2010-11 to 2021-22)

Response variable	Growth Function	Coefficients		R ²	RMSE	F Value	Growth rate (% per annum)
		β ₀	β ₁				
Area	Linear	16241.67	320.57	0.45	1324.91	8.37	1.74*
	Semi log	9.697	0.017	0.46	0.0722	8.56	1.76*
	Exponential	9.68	0.077	0.39	0.0766	6.46	2.86*
Production	Linear	24569.20	12789.21	0.57	41275.61	13.72	11.87*
	Semi log	10.83	0.099	0.68	0.2533	21.92	9.91*
	Exponential	10.83	0.392	0.47	0.3284	8.99	14.45*
Productivity	Linear	2072.10	566.35	0.54	1965.71	11.87	9.84*
	Semi log	8.0503	0.0815	0.60	0.2487	15.36	8.15*
	Exponential	8.055	0.315	0.39	0.3074	6.60	11.59*

Note: - * indicates 1 percent level of significance

Table 2. Growth rate in area, production, and productivity of tomato in Jaipur district of Rajasthan (2010-11 to 2021-22)

Response variable	Growth Function	Coefficients		R ²	RMSE	F Value	Growth rate (% per annum)
		β_0	β_1				
Area	Linear	6639.36	454.09	0.82	785.14	47.83	4.73*
	Semi log	8.855	0.045	0.86	0.067	65.34	4.58*
	Exponential	8.82	0.196	0.69	0.1021	23.28	7.23*
Production	Linear	21874.70	10136.05	0.44	42788.25	8.0246	23.03*
	Semi log	9.2177	0.1594	0.46	0.6469	8.688	15.94*
	Exponential	9.34	0.543	0.23	0.772	3.117	20.00 ^{NS}
Productivity	Linear	-474.44	690.23	0.39	3222.96	6.55	17.20**
	Semi log	7.270	0.113	0.33	0.6057	5.02	11.35**
	Exponential	7.429	0.347	0.13	0.6896	1.594	12.77 ^{NS}

Note: - * indicates 1 percent level of significance, ** 5 percent level of Significance and NS indicates Non-Significant

Table 3. Growth rate in area, production, and productivity of tomato in the Sirohi district of Rajasthan (2010-11 to 2021-22)

Response variable	Growth Function	Coefficients		R ²	RMSE	F Value	Growth rate (% per annum)
		β_0	β_1				
Area	Linear	1287.89	-4.95	0.003	321.84	0.033	-0.39 ^{NS}
	Semi log	7.1256	-0.002	0.001	0.241	0.014	-0.23 ^{NS}
	Exponential	7.1557	-0.0274	0.008	0.240	0.081	0.01^{NS}
Production	Linear	14642.98	1088.45	0.34	5618.68	5.366	5.01**
	Semi log	9.5683	0.05606	0.31	0.3134	4.574	5.60***
	Exponential	9.4235	0.305	0.41	0.2906	6.955	11.24**
Productivity	Linear	12727.98	857.104	0.18	6749.103	2.306	4.68 ^{NS}
	Semi log	9.350	0.0548	0.22	0.4158	2.826	5.84 ^{NS}
	Exponential	9.175	0.333	0.31	0.3898	4.589	12.25***

Note: - ** and *** indicates 5 and 10 percent level of Significance and NS indicates Non-Significant

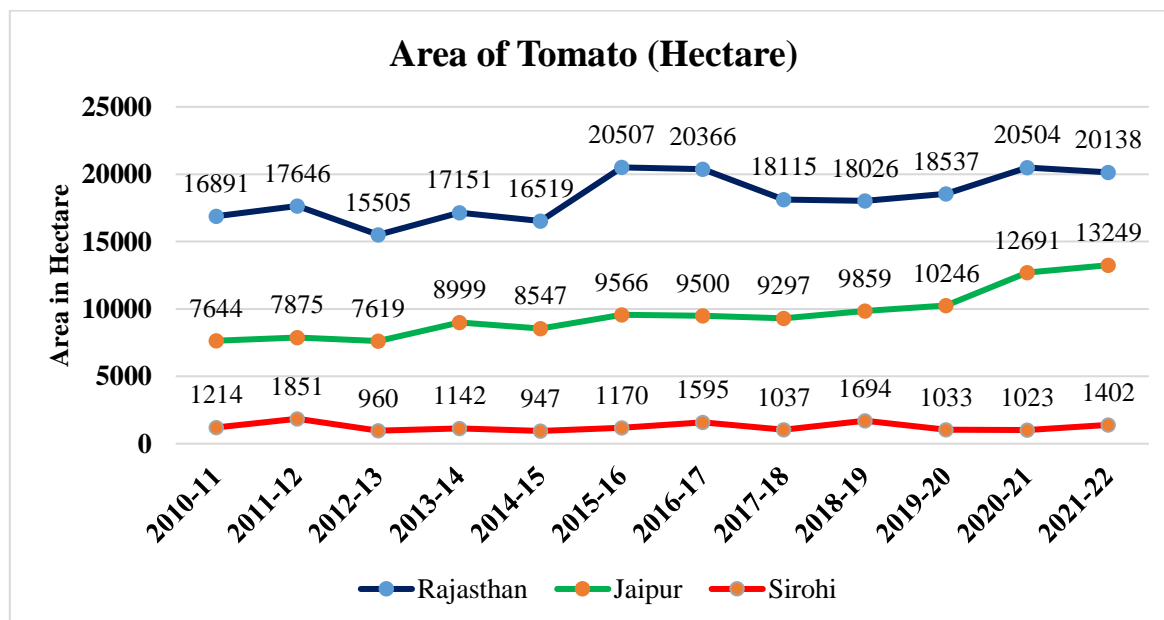


Fig. 1. Area of Tomato in Rajasthan state with Jaipur and Sirohi district

The productivity show 12.25 percent compound annual growth rate with 10 percent level of significance. The productivity of tomato show more fluctuation in the Sirohi district because fruit set in tomato influenced by the fluctuations in the temperature and humidity. During the year August 2015 the maximum temperature was

35°C with 98 percent humidity, in the same minimum temperature and humidity was 25 °C and 46 percent respectively. In the August 2016 the maximum temperature and humidity was 36°C and 100 percent and the minimum temperature of this period was 24°C with 49 percent humidity.

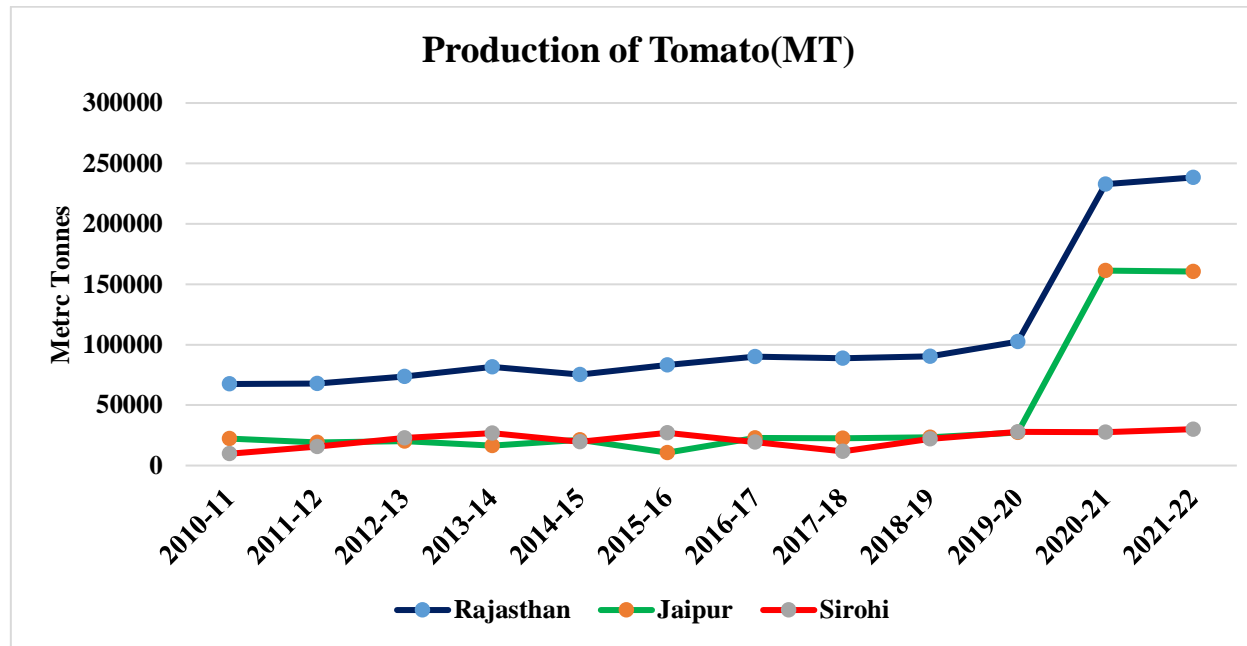


Fig. 2. Production of Tomato in Rajasthan state with Jaipur and Sirohi district

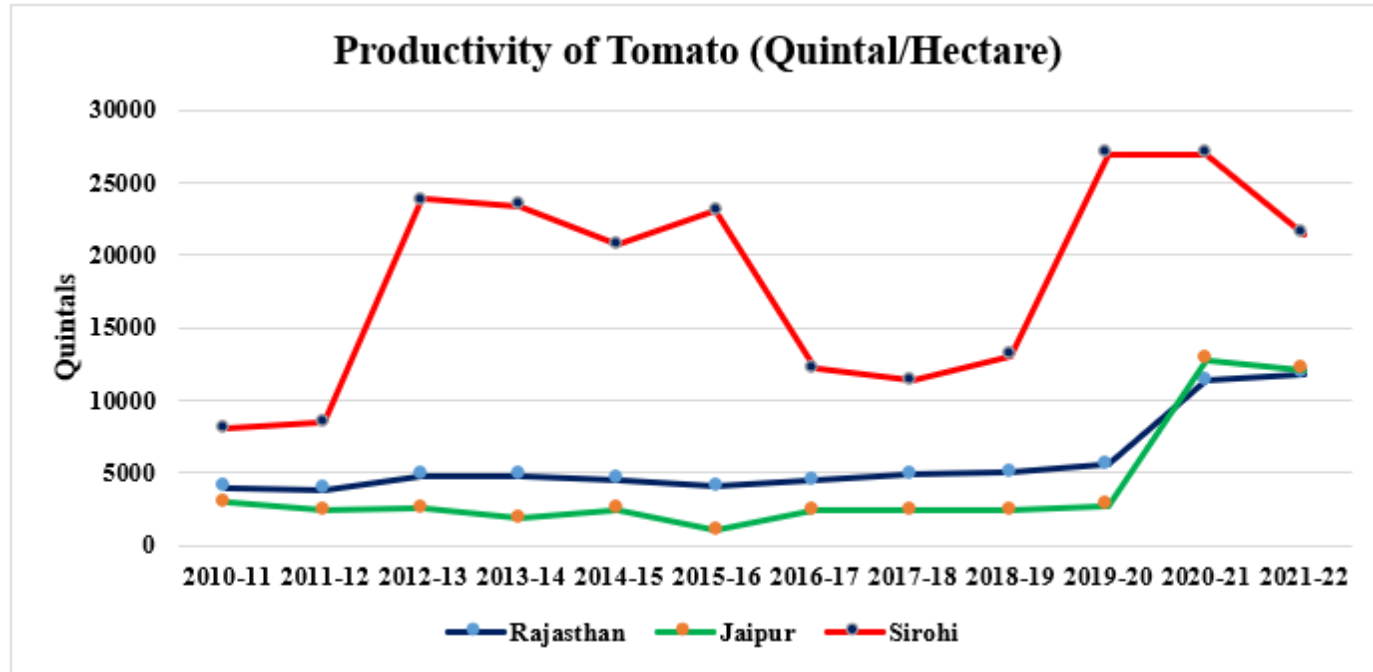


Fig. 3. Productivity of Tomato in Rajasthan state with Jaipur and Sirohi district

4. DISCUSSION AND CONCLUSION

The area, production and productivity of Rajasthan shows significantly positive growth rate during the 12 year study period from 2010-11 to 2021-22. The compound annual growth rate for area was found 1.76 percent, that increase from 16891 to 20138 hectare in the study period. The production and productivity shows 9.91 and 8.15 percent compound annual growth rate that was increased from 67466 MT to 238393 MT in production and productivity was increased from 3994 to 11838 quintal per hectare. Jaipur district also show positive growth trend in area, production and productivity of tomato. The area show 4.58 percent compound annual growth rate that was increased from 7644 to 13249 hectare. The production was increased from 22437 MT to 160586 MT, which shows 15.94 percent compound annual growth rate of tomato in Jaipur district. The productivity was increased from 2935 to 12121 quintal per hectare which show 17.20 percent compound annual growth rate at 5 significant level. The area of Sirohi district was increased from 1214 to 1402 hectare, which show non-significant compound annual growth in area of tomato in Sirohi district. The production shows 11.24 percent compound annual growth in tomato production at 5 percent significant level. It was increased from 9741 to 30110 MT per hectare. The productivity was increased from 8024 to 21476 quintal per hectare with 12.25 percent compound annual growth at 10 percent significant level. Thus the productivity shows highest compound annual growth rate followed by Production and area in Rajasthan state as well as Jaipur and Sirohi district of Rajasthan. Introduction of the high yielding varieties, can be helpful in the increase in the productivity of tomato in Rajasthan. Apart from this Jaipur and Sirohi district are major tomato cultivating district of Rajasthan while both have huge difference in cultivated area, which is 13249 and 1402 hectare for the Jaipur and Sirohi district respectively. Tomato is a major contributing vegetable to the processing industry and has many by-products, for which the area under tomato cultivation should also be increased by showing the benefits of tomato to the farmers through extension activity.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image

generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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