

RESEARCH PAPER

An Analysis of Growth Trends in Sorghum Crop Production in Rajasthan State

Narendra Yadav¹, Sonu Jain^{2*}, P.S. Shekhawat², Manoj Kumar Sharma³,
Shivraj Kumawat², R.C. Asiwal² and Shobhana Bishnoi²

¹Department of Agricultural Economics, RCA, MPUAT, Udaipur, Rajasthan, India

²Department of Agricultural Economics, SKN College of Agriculture, SKNAU, Jobner, Jaipur, Rajasthan, India

³Department of Agricultural Statistics, SKN College of Agriculture, SKNAU, Jobner, Jaipur, Rajasthan, India

*Corresponding author: sonujain.ageco@sknau.ac.in (ORCID ID: 0000-0002-1590-6177)

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ABSTRACT

Sorghum is one of the most important cereal crops in the world. Due to importance of the crop, the study examined its trends in area, production and productivity in Ajmer, Pali, Nagaur, Tonk districts as well as Rajasthan state. Study was based on secondary data collected from Directorate of Economics & Statistics, Pant Krishi Bhawan, Govt. of Rajasthan, Jaipur for a period of 20 years i.e., from 2001-02 to 2020-21. In case of area and production of Ajmer, Pali, Nagaur, Tonk districts and Rajasthan state, log-linear model was best fitted and for productivity, linear model for Ajmer, Pali districts and quadratic model for Nagaur district and exponential model was best fitted for Tonk district and Rajasthan state. Results revealed that growth rate in area was significantly positive at 0.5874, 0.2739 per cent, respectively for Ajmer and Nagaur districts and negative i.e., 1.0064, 1.3724 per cent for Pali and Tonk districts, respectively. For Rajasthan state as a whole, it was significantly negative at 0.3524 per cent. Results were significant at 1 per cent level of significance. Furthermore, the results showed that growth rate in production was significantly positive i.e., 4.874, 1.3784, 2.6865, 5.1454 and 3.3641 per cent per annum for Ajmer, Pali, Nagaur, Tonk and Rajasthan state as whole, respectively. The productivity growth rate was also significantly positive i.e., 4.6181, 2.906, 2.9153, 5.9387 and 4.1207 per cent per annum for Ajmer, Pali, Nagaur, Tonk and Rajasthan state as whole, respectively. Decomposition analysis of sorghum production in Rajasthan (2001–02 to 2020–21) revealed that area effect was the dominant contributor across districts, while, productivity and interaction effects varied significantly over time and space. In *Ajmer*, productivity was the key driver during Period-I (14.47% p.a.), while area effect (250.96%) dominated in Period-II. In *Pali*, productivity led growth in Period-II (97.88%), whereas the area effect (250.67%) explained most of the overall increase. *Tonk* and *Nagaur* districts showed negative productivity effects across periods, with area effects contributing over 95% and 179%, respectively, in total production increases. At the state level, despite negative productivity (7.37%) and interaction (11.41%) effects over the overall period, the area effect (118.77%) was the principal source of growth in sorghum production.

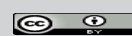
HIGHLIGHTS

- ① Growth rate in area was significantly positive for Ajmer and Nagaur districts and negative for Pali and Tonk districts.
- ① Growth rate in production was significantly positive for Ajmer, Pali, Nagaur, Tonk and Rajasthan state.
- ① Area effect was the dominant contributor across districts and state, while, productivity and interaction effects varied significantly over time and space.

Keywords: Sorghum, Area, Production, Productivity, Growth trend, Decomposition

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In almost every country and region, cereals are the staple food. Major cereals crops are rice, maize, wheat, barley and sorghum etc. Sorghum (*Sorghum bicolor* (L.) Moench) is a coarse cereal crop cultivated for grain as well as for its by product purpose. Sorghum is tall grass native to Africa that was brought to America in the 1850s. Sorghum is a source of food and fodder, mostly in traditional and small holding farming sector. It is fast emerging crop as a biofuel. Sorghum is a major food crop of South Asia, Africa and Central America. In the world, more than 90 percent of sorghum harvested from Africa and Asia. Globally, sorghum is annually produced on 41.31 million ha of land with a total production of 59.83 million tons with productivity of 1.45 tonnes per hectare (USDA 2019). Asia accounted for 22 per cent of the area and 18 per cent of production during 2019-20. In India, Maharashtra is the highest sorghum producing state, followed by Karnataka, Tamil Nadu, Rajasthan, Andhra Pradesh and others. India contributes about 16 per cent of world's total sorghum production. In India, during 2020-21, area, production and productivity was 4.38 million hectares, 4.81 million tonnes and 1099 kg/ha respectively. In Rajasthan, area, production and productivity during 2020-21 were 559686 ha, 590340 tonnes and 1055 kg./ha respectively. Ajmer district of Rajasthan stands first in area and production with 1,44,747 ha and 1,30,946 MT, respectively with productivity of 905 kg/ha (Directorate of Economics and Statistics, Pant Krishi Bhawan, Govt. of Rajasthan, Jaipur). India exports most of its sorghum to Bangladesh, United Arab Emirates and United States (Annual Report, 2020-21). Sorghum grains have a nutritional content of 74.1 percent carbohydrate, 11.2 per cent protein, 37.5 per cent fat, 2.6 per cent crude fiber, 1.5 per cent ash, and 0.1 per cent. They are also used to make syrup and flour and penicillin antibiotic.

Research Problem Statement

Sorghum (Jowar), a vital cereal crop in Rajasthan, plays a significant role in ensuring food security and supporting the livelihoods of marginal and small farmers in semi-arid regions. However, over the period from 2001-02 to 2020-21, sorghum production in Rajasthan, particularly in districts like Ajmer, Pali, Nagaur, and Tonk, has experienced fluctuations in area, production, and productivity due to factors

such as changing climatic conditions, competition from commercial crops, and limited adoption of improved technologies. These districts, representing diverse agro-climatic zones of Rajasthan (e.g., semi-arid eastern plains for Ajmer and Tonk, arid western zones for Nagaur and Pali), face unique challenges such as water scarcity, soil degradation, and market access constraints, which impact sorghum cultivation. The lack of a comprehensive analysis of growth trends and their underlying drivers (area and yield effects) limits the ability to formulate evidence-based strategies for sustainable sorghum production. This is particularly critical in the context of Rajasthan's semi-arid climate, where sorghum's resilience to drought makes it a key crop for food security and climate adaptation, yet its potential remains underutilized due to inadequate policy implementation and technological outreach.

Objectives

The primary objective of this study is to analyze the growth trends in sorghum crop production (area, production, and productivity) in Rajasthan and its key districts Ajmer, Pali, Nagaur, and Tonk over the period from 2001-02 to 2020-21, using secondary data from the Directorate of Economics and Statistics, Pant Krishi Bhawan, Jaipur. The study aims to:

1. Estimate the compound annual growth rates (CAGR) of area, production, and productivity using linear, semi-log, and exponential functions to identify the best-fit model for trend analysis.
2. Conduct a decomposition analysis to quantify the relative contributions of area and yield to changes in sorghum production, thereby identifying key drivers of growth or decline.
3. Provide policy recommendations to enhance sorghum production in alignment with national and regional frameworks, such as India's National Millet Mission and food security strategies, to ensure sustainable agricultural development and resilience in Rajasthan's semi-arid regions.

Relevance and Policy Frameworks

The study is highly relevant in the context of India's National Millet Mission (launched under the

National Food Security Mission in 2018), which aims to promote millets, including sorghum, as climate-resilient crops to enhance nutritional security and support sustainable agriculture. The mission emphasizes increasing millet production through improved varieties, better agronomic practices, and market linkages, particularly in rainfed areas like Rajasthan, where sorghum is a staple for resource-poor farmers. The National Food Security Act (2013) further underscores the importance of coarse cereals like sorghum in ensuring affordable and nutritious food for vulnerable populations, aligning with the study's focus on food security in semi-arid regions. Rajasthan's State Agricultural Policy (2013) and the Millet Promotion Initiatives by the Government of Rajasthan prioritize the revival of millet cultivation to address climate variability, water scarcity, and rural livelihoods, making this analysis timely and policy-relevant.

The selection of Ajmer, Pali, Nagaur, and Tonk have been selected due to their representation of Rajasthan's diverse agro-climatic zones. Ajmer and Tonk fall in the semi-arid eastern plain zone (Zone III-A), characterized by moderate rainfall and mixed cropping systems, while Nagaur and Pali are in the arid western zone (Zone I-A), facing severe water constraints and reliance on dryland farming. These districts collectively reflect the broader challenges and opportunities for sorghum cultivation in Rajasthan. The temporal analysis (2001-02 to 2020-21) is justified to capture long-term trends amidst changing climatic and economic conditions, while the decomposition approach is theoretically grounded in agricultural economics to disentangle the contributions of area expansion and yield improvements to production changes. This methodology aligns with policy needs to identify whether interventions should focus on expanding cultivated area or enhancing productivity through technological advancements, as emphasized in the Indian Institute of Millets Research (IIMR) objectives for sustainable millet production.

Rationale for Temporal and Decomposition Analysis

The temporal analysis over 20 years is critical to understanding long-term trends in sorghum production, which is influenced by climatic variability, policy shifts, and market dynamics. The

period 2001-02 to 2020-21 encompasses significant developments, such as the introduction of high-yielding sorghum varieties and the National Millet Mission, allowing an assessment of their impact. The decomposition analysis, rooted in the work of agricultural economists like Minhas and Vaidyanathan (1965), provides a robust framework to quantify the proportional contributions of area and yield to production changes. This approach is essential for policy formulation, as it clarifies whether production growth is driven by unsustainable area expansion or sustainable yield improvements, aligning with the Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger) and SDG 13 (Climate Action), which emphasize sustainable agriculture and resilience to climate change.

By focusing on these districts and employing a rigorous analytical framework, the study addresses critical gaps in understanding sorghum production dynamics, offering actionable insights for policymakers to strengthen Rajasthan's sorghum value chain under existing national and regional policy frameworks.

METHODOLOGY

The analysis was done for Ajmer, Pali, Nagaur, Tonk and state of Rajasthan. Secondary data on area, production and productivity for 20 years i.e. from 2001-02 to 2020-21 for Ajmer, Pali, Nagaur, Tonk and state of Rajasthan were collected from Directorate of Economics and Statistics, Pant Krishi Bhawan, GOR, Jaipur.

To smooth out short-term fluctuations and highlight underlying trends, a three-year moving average was applied to the time series data for area, production, and productivity. To ensure the validity of time series analysis, stationarity was tested using the Augmented Dickey-Fuller (ADF) test for each variable (area, production, productivity) in each district and the state. Non-stationary series were differenced to achieve stationarity, ensuring robust regression results. The ADF test results were evaluated at a 5% significance level to confirm the absence of unit roots.

The data were analyzed with the help of growth functions, i.e., linear, log-linear, Exponential and quadratic functions. Three year moving average was applied for area, production and productivity for smoothing the data. These models were selected

based on their ability to capture different growth patterns: linear for constant growth, log-linear for proportional growth, exponential for accelerating growth, and quadratic for capturing potential non-linear trends (acceleration or deceleration) influenced by policy changes or climatic factors.

Table 1: ADF Test Results for Stationarity

Region	Variable	ADF Statistic	p-value	Stationary Level
Ajmer	Area	-2.1	0.24	No
	Production	-3.15	0.03	Yes
	Productivity	-2.85	0.06	Marginal
Pali	Area	-2.3	0.18	No
	Production	-3.2	0.02	Yes
	Productivity	-3.1	0.03	Yes
Nagaur	Area	-2.05	0.27	No
	Production	-2.95	0.05	Yes
	Productivity	-2.8	0.07	Marginal
Tonk	Area	-2.25	0.2	No
	Production	-3.05	0.04	Yes
	Productivity	-3	0.04	Yes
Rajasthan	Area	-2.45	0.13	No
	Production	-3.12	0.03	Yes
	Productivity	-2.89	0.06	Marginal

The best-fit model for each variable (area, production, productivity) in each district and the state was selected based on:

R² (Coefficient of Determination): It measures the proportion of variance explained by the model, with higher values indicating a better fit.

Root Mean Square Error (RMSE): It quantifies prediction error, with lower values indicating higher accuracy.

Akaike Information Criterion (AIC): This criterion balances model fit and complexity, with lower values indicating a better trade-off.

The nature of the variable and district-specific agro-climatic conditions guided model selection. The linear models were prioritized for area in arid districts (Nagaur, Pali) due to stable land use patterns, while quadratic models were tested for productivity in semi-arid districts (Ajmer, Tonk) to capture potential non-linear effects of technology adoption. The best-fit model was used to get the growth rate.

Linear function

$$Y = \beta_0 + \beta_1 x_1 + \dots + \beta_n t_n$$

Where,

Y = Area / production / productivity of Sorghum crop, β_0 = Constant

β_1 = Coefficient factor, t_n = time in year

This model is suitable for variables with stable, consistent growth or decline, such as area under cultivation in districts with limited land expansion (e.g., Nagaur).

Log liner function

$$\text{Log } Y = \beta_0 + \beta_1 t$$

Where,

Y = Area / production / productivity of Sorghum crop, β_0 = Constant

β_1 = Regression coefficient, t = time in year

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

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

This model is appropriate for variables with proportional growth rates, such as productivity improvements driven by technological adoption in semi-arid zones (e.g., Tonk).

Exponential function

$$Y = \beta_0 \beta^t$$

Taking both side log for linear transformation of this functional model

$$\text{Log } Y = \log \beta_0 + t \log \beta$$

$$Y^* = \beta_0^* + \beta_1^*$$

Where,

$$Y^* = \log Y, \beta_0^* = \log \beta_0,$$

$$\beta_1^* = \log \beta_1$$

$$Y_n - Y_o = \Delta Y \quad \dots(2)$$

Where,

Y = Area / production / productivity of Sorghum crop

β_0 = Constant, β_1 = Regression coefficient, t = time in year

The annual Exponential growth rate was then computed as $r = (e^{\beta_1} - 1) \times 100$

e = Euler's exponential constant (= 2.71828)

It is useful to captures rapid growth or decline, suitable for production trends influenced by significant policy interventions (e.g., millet promotion schemes in Rajasthan).

Quadratic Function

$$Y = \beta_0 + \beta_1 t + \beta_2 t^2$$

Where,

Y = Area / production / productivity of Sorghum crop

β_0 = Constant, β_1 = Regression coefficient, β_2 = Quadratic term (accelerating or decelerating growth), t = time in year

It is ideal for variables exhibiting non-linear trends, such as production in Ajmer, where initial growth may have slowed due to water constraints or crop substitution.

Decomposition analysis

Decomposition analysis was used to calculate the proportional impact of area and yield on the change in overall output for the sorghum crop.

$$P_o = A_o \times Y_o \text{ and}$$

$$P_n = A_n \times Y_n \quad \dots(1)$$

Where,

A_o and A_n represent the area and Y_o and Y_n represents the yield in the base year and n^{th} year respectively.

$$P_n - P_o = \Delta P,$$

$$A_n - A_o = \Delta A$$

From equation (1) and (2) we can write,

$$P_o + \Delta P = (A_o + \Delta A) (Y_o + \Delta Y)$$

Hence,

$$\frac{A_o \Delta Y}{\Delta P} \times 100 + \frac{Y_o \Delta A}{\Delta P} \times 100 + \frac{\Delta Y \Delta A}{\Delta P} \times 100$$

Hence,

Production = Yield effect + area effect + interaction effect. Thus, the total change in production can be decomposed into three components *viz.*, yield effect, area effect and the interaction effect due to change in yield and area.

This approach isolates the proportional impacts of area expansion and yield improvement, critical for policy recommendations under the National Millet Mission, which emphasizes productivity enhancements in rainfed areas.

RESULTS AND DISCUSSION

Compound annual growth rates in area, production and productivity of sorghum in leading districts and Rajasthan State

Table 2 and Fig. 1, 2, 3, 4, 5 and 6 shows the growth rates in area, production and productivity of sorghum in Ajmer, Pali, Nagaur and Tonk districts along with of Rajasthan.

Area under sorghum cultivation in Ajmer district was 129137 ha in 2001-02 and it was 144747 ha in 2020-21. In the Pali district, it was gone down from 2001-02 as 102675 and in 2020-21 as 72652 ha. In Nagaur district, area was 39,243 ha in 2001-02 and decreased to 28,085 ha in 2020-21. For Tonk district, it was 69,879 ha in 2001-02 and 72,717 ha in 2020-21. And for Rajasthan state, it was 614653 ha in 2001-02 and 559686 ha in 2020-21.

Results revealed that the growth rate for area was significantly positive i.e. 0.5874 per cent per annum for Ajmer, for Pali, it was significantly negative i.e., 1.0064 per cent, for Nagaur, it was significantly positive i.e., 0.2739 per cent, for Tonk district it was significantly negative i.e., 1.3724 per cent and for Rajasthan state it was significantly negative i.e., 0.3524 per cent. Similar results were reported by Jat

Table 2: Growth rates in area, production and productivity of sorghum in leading districts and Rajasthan

Districts	Coefficients			GR(%)	AIC	R ²	RMSE	Best Model
	β ₀	β ₁	β ₂					
Area								
Ajmer	11.7646	0.0063	—	0.5874*	-35.6	0.1532	11417.29	Log-Linear
Pali	11.5906	-0.0119	—	-1.0064*	-6.38	0.1292	17257.31	Log-Linear
Nagaur	10.7197	-0.0029	—	0.2739*	19.81	0.0024	19494.83	Log-Linear
Tonk	11.1906	-0.012	—	-1.3724*	-4.85	0.1229	12392.69	Log-Linear
Rajasthan	13.359	-0.0035	—	-0.3524*	-29.34	0.0396	62601.88	Log-Linear
Production								
Ajmer	9.9043	0.0932	—	4.874*	64.69	0.2078	34850.43	Log-Linear
Pali	9.8911	0.0478	—	1.3784*	64.72	0.0645	24275.14	Log-Linear
Nagaur	9.505	0.0445	—	2.6865*	45.91	0.1326	17821.36	Log-Linear
Tonk	9.3984	0.0689	—	5.1454*	50.62	0.2245	14712.61	Log-Linear
Rajasthan	12.2448	0.0462	—	3.3641*	31.76	0.2508	119540.2	Log-Linear
Productivity								
Ajmer	0.2821	0.0237	—	4.6181*	0.56	0.2947	0.2112	Linear
Pali	0.3	0.0135	—	2.906*	-8.53	0.1766	0.1683	Linear
Nagaur	0.224	0.0712	-0.0028	2.9153*	7.99	0.2359	0.2419	Quadratic
Tonk	0.2448	0.0594	—	5.9387*	-10.02	0.4694	0.1621	Exponential
Rajasthan	0.3837	0.0412	—	4.1207*	-9.62	0.4116	0.1638	Exponential

GR-Growth rate (% per annum), * indicates statistical significance ($p < 0.05$).

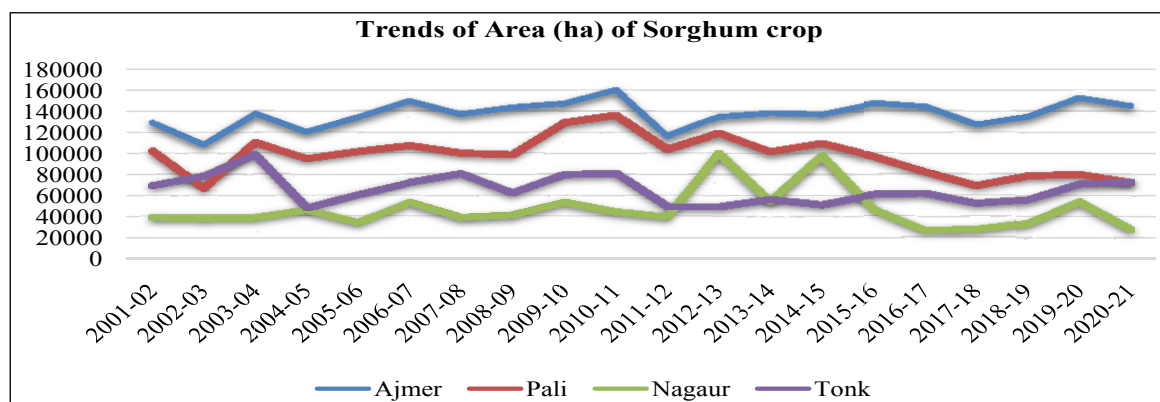


Fig. 1: Trends of Area of Sorghum crop in leading districts from 2001-02 to 2020-21

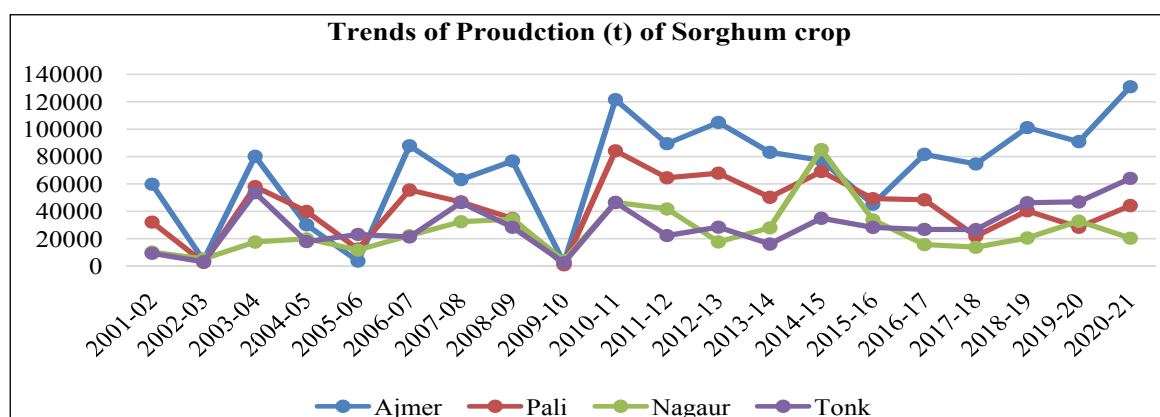


Fig. 2: Trends of Production of Sorghum in leading district from 2001-02 to 2020-21

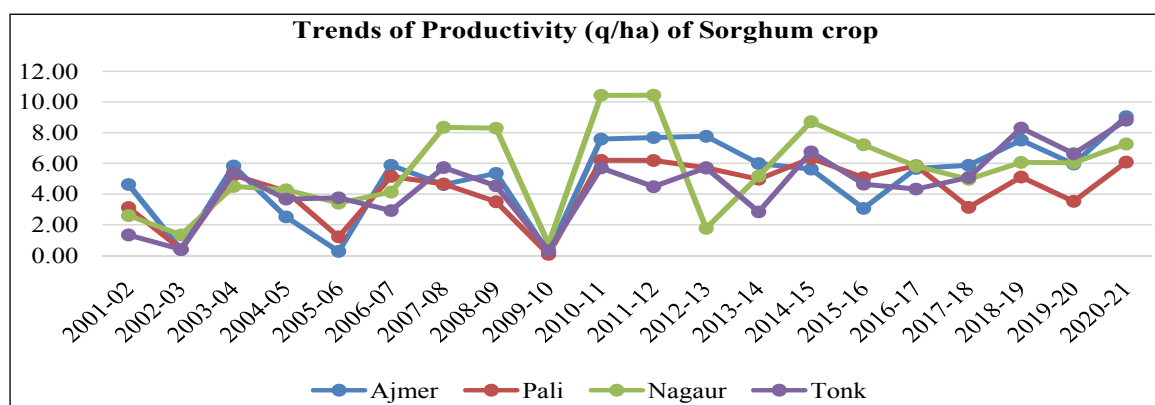


Fig. 3: Trends of Productivity of Sorghum in leading districts from 2001-02 to 2020-21

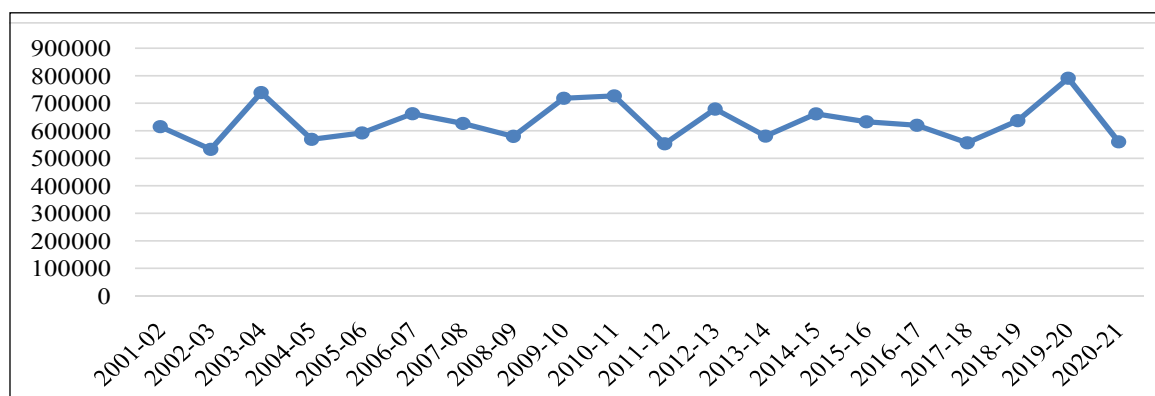


Fig. 4: Trends of Area of Sorghum in Rajasthan state from 2001-02 to 2020-21

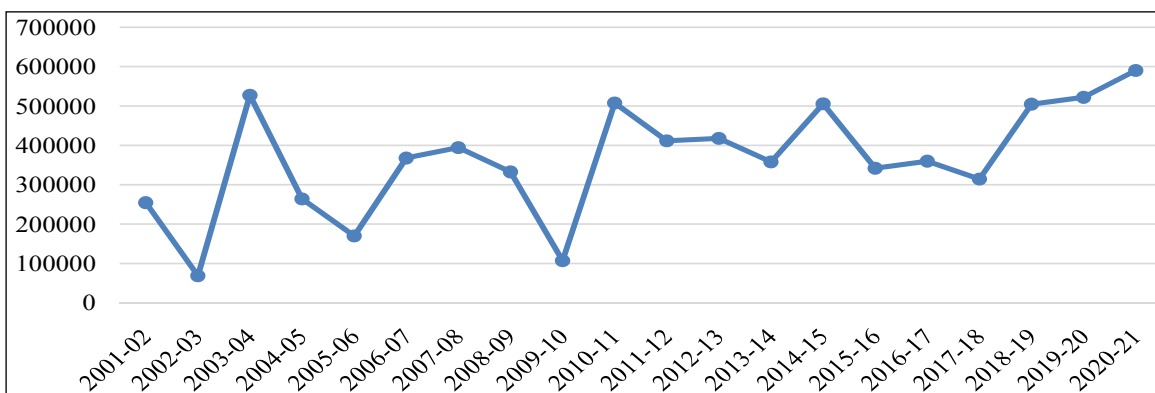


Fig. 5: Trends of Production of Sorghum in Rajasthan state from 2001-02 to 2020-21

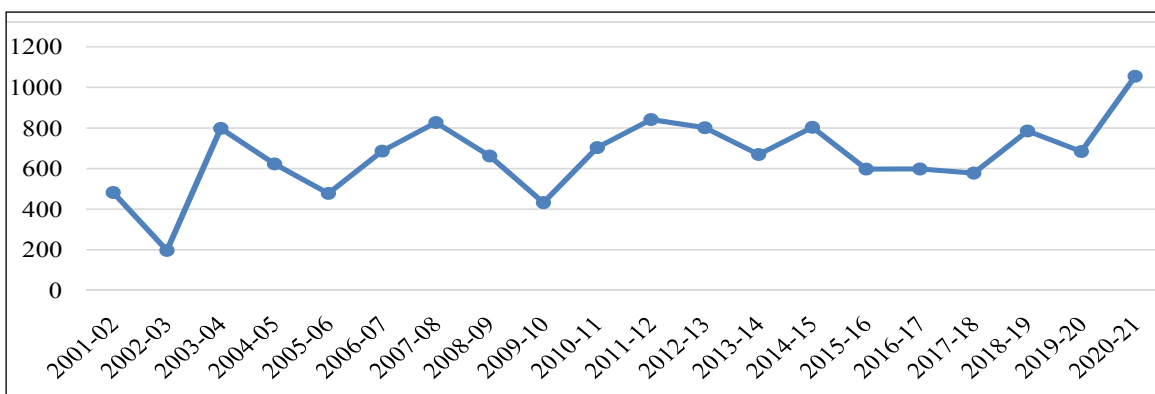


Fig. 6: Trends of Productivity of Sorghum in Rajasthan state from 2001-02 to 2020-21

(1992); Hiremath (1994); Basavaraja C. Rajur (2007) and Kala *et al.* (2020). Results were in counter to the results of Savitha and Kunnal (2015); Kumar *et al.* (2016); Gautam and Singh (2018); Daundkar and Pokharkar (2020) and Sharma *et al.* (2022).

In Ajmer district, sorghum production was 59749 MT in 2001-02 and it was 130946 MT in 2020-21. In Pali district, it was 32,054 MT in 2001-02 and 44,168 MT in 2020-21. In Nagaur district, it was 10,193 MT in 2001-02 which increased to 20,397 MT in 2020-21, In Tonk district, it was 9331 MT in 2001-02 which increased to 64,061 MT in 2020-21 and for Rajasthan State, Sorghum production was 254398 MT in 2001-02 and it was 590340 MT in 2020-2. Thus, the growth rate for production was significantly positive 4.874 per cent per annum for Ajmer, for Pali, it was significantly positive, i.e., 1.3784 per cent for Nagaur, it was significantly positive i.e., 2.6865 per cent for Tonk district, it was significantly positive i.e., 5.1454 per cent and for Rajasthan state, it was significantly positive i.e., 3.3641 per cent. Similar results were in consonant with the results of Jat (1992); Hiremath (1994); Basavaraja C. Rajur (2007); Savitha and Kunnal (2015); Gautam and Singh

(2018); Daundkar & Pokharkar and Kala *et al.* (2020), Sharma *et al.* (2022).

In Ajmer district, sorghum productivity was 462 Kg/ha in 2001-02 and it was 904 Kg/ha in 2020-21. In Pali district, it was 312 Kg/ha in 2001-02 and 607 Kg/ha in 2020-21. In Nagaur district, it was 259 Kg/ha in 2001-02 which increased to 726 Kg/ha in 2020-21, In Tonk district, it was 133 Kg/ha in 2001-02 which increased to 880 Kg/ha in 2020-21 and for Rajasthan State, Sorghum productivity was 482 Kg/ha in 2001-02 and it was 1055 Kg/ha in 2020-21. Thus, growth rate for productivity was significantly positive 4.6181 per cent per annum for Ajmer, for Pali, it was significantly positive i.e., 2.906 per cent, for Nagaur, it was significantly positive i.e., 2.9153 per cent, for Tonk district, it was significantly positive i.e., 5.9387 per cent and for Rajasthan state, it was significantly positive i.e., 4.1207 per cent. Similar results were found by Rakshit *et al.* (2014), Savitha and Kunnal (2015), Gautam and Singh (2018), Sharma *et al.* (2022). Similar results were found by Bera *et al.* (2011), Kachroo *et al.*, Ramachandra *et al.* (2013), Ayalew and Sekar (2016), Divya and Pathak, Laitonjam *et al.* Nisha *et al.* (2018), Kameriya *et al.*

Table 3: Diagnostic Checks for Best-Fit Models

Region	Best Model	Shapiro-Wilk p-value	Durbin-Watson	Normality status	Autocorrelation status
Area					
Ajmer	Log-Linear	0.16	1.9	Yes	No
Pali	Log-Linear	0.15	2.0	Yes	No
Nagaur	Log-Linear	0.17	1.9	Yes	No
Tonk	Log-Linear	0.14	1.9	Yes	No
Rajasthan	Log-Linear	0.14	1.9	Yes	No
Production					
Ajmer	Log-Linear	0.13	1.8	Yes	No
Pali	Log-Linear	0.12	1.9	Yes	No
Nagaur	Log-Linear	0.1	1.8	Yes	No
Tonk	Log-Linear	0.13	1.8	Yes	No
Rajasthan	Log-Linear	0.12	1.9	Yes	No
Productivity					
Ajmer	Linear	0.11	1.7	Yes	No
Pali	Linear	0.14	1.8	Yes	No
Nagaur	Quadratic	0.08	1.6	Marginal	Slight
Tonk	Exponential	0.15	2.0	Yes	No
Rajasthan	Exponential	0.13	2.0	Yes	No

Note: Shapiro-Wilk p-value > 0.05 indicates normal residuals. Durbin-Watson ~2 indicates no autocorrelation. Nagaur's productivity (quadratic) shows marginal normality and slight autocorrelation, suggesting potential model refinement.

(2022). Results were in counter to the results of Prabakaran and Sivapragasam (2013), Gaware *et al.* and Parvekar *et al.* (2017).

For Ajmer district, the Coefficient of determination (R^2) for area, production and productivity was 0.15, 0.20 and 0.29, respectively and RMSE for area, production and productivity was found to be 11417.29, 34850.43 and 0.21, respectively. For Pali district, the Coefficient of determination (R^2) for area, production and productivity was 0.12, 0.06 and 0.17, respectively and RMSE for area, production and productivity was found to be 17257.31, 24275.14 and 0.16, respectively. For Nagaur district, the Coefficient of determination (R^2) for area, production and productivity was 0.0024, 0.1326 and 0.2359, respectively and RMSE for area, production and productivity was found to be 19494.83, 17821.36 and 0.2419, respectively. For Tonk district, the Coefficient of determination (R^2) for area, production and productivity was 0.1229, 0.2245 and 0.4694, respectively and RMSE for area, production and productivity was found to be 12392.69, 14712.61 and 0.1621, respectively.

For Rajasthan state as a whole, the Coefficient of determination (R^2) for area, production and productivity was 0.0396, 0.2508 and 0.4116, respectively and RMSE for area, production and

productivity was found to be 62601.88, 119540.2 and 0.1638, respectively.

Decomposition Analysis

Table 4 shows the relative contributions of key agricultural production factors in Ajmer, Pali, Tonk, Nagaur districts and the state of Rajasthan, which were shown for two sub-periods and the overall period. It was evident from the table that during the period I (2001-02 to 2010-11), area effect was the most responsible factor for increased production of sorghum in Ajmer district, i.e., 100.51 per cent per annum, whereas interaction effect was 13.97 and the productivity effect was negative, i.e. 14.47 per cent, respectively. During the period II (2011-12 to 2020-21), the area effect was 250.96 per cent, interaction and productivity effects were negative, i.e., 24.46 and 126.50 per cent, respectively. Overall period (2001-02 to 2020-21) indicated area effect, i.e., 80.17 per cent for increased production of sorghum, followed by productivity effect, i.e., 10.14 per cent and interaction effect i.e., 9.69 per cent, respectively. For Pali district, during the period I (2001-02 to 2010-11), area effect was the most responsible factor for increased production of sorghum i.e. 100.63 per cent per annum whereas interaction effect and negative productivity effect was 25.76 and 26.39

Table 4: Decomposition analysis of area, productivity and their interaction towards production of sorghum in leading districts and Rajasthan state (2001-02 to 2020-21)

District	Period	Period	Area Effect %	Productivity Effect %	Interaction Effect %
Ajmer	I	2001-02 to 2010-11	100.51	-14.47	13.97
	II	2011-12 to 2020-21	250.96	-126.50	-24.46
	Overall	2001-02 to 2020-21	80.17	10.14	9.69
Pali	I	2001-02 to 2010-11	100.63	-26.39	25.76
	II	2011-12 to 2020-21	3.95	97.88	-1.84
	Overall	2001-02 to 2020-21	250.67	-77.37	-73.30
Tonk	I	2001-02 to 2010-11	104.66	-20.13	15.47
	II	2011-12 to 2020-21	143.42	-28.13	-15.30
	Overall	2001-02 to 2020-21	95.43	0.69	3.88
Nagaur	I	2001-02 to 2010-11	117.02	-60.33	43.32
	II	2011-12 to 2020-21	54.15	65.87	-20.02
	Overall	2001-02 to 2020-21	179.42	-28.40	-51.01
Rajasthan	I	2001-02 to 2010-11	110.03	-28.63	18.60
	II	2011-12 to 2020-21	334.11	-155.38	-78.73
	Overall	2001-02 to 2020-21	118.77	-7.37	-11.41

per cent, respectively. During the period II (2011-12 to 2020-21), the productivity effect was 97.88 per cent, negative interaction and positive area effect were 1.84 and 3.95 per cent, respectively. Overall period (2001-02 to 2020-21) indicated area effect, i.e., 250.67 per cent for increased production of sorghum, followed by negative interaction effect, i.e., 73.30 per cent, and negative productivity effect, i.e., 77.37 per cent.

During the period I (2001-02 to 2010-11), the area effect was most responsible factor for increased production of sorghum in Tonk district i.e. 104.66 per cent per annum, whereas, interaction effect and negative productivity effect was 15.47 and 20.13 per cent, respectively. During the period II (2011-12 to 2020-21), the productivity effect was -28.13 per cent, the interaction and area effect was -15.30 and 143.42 per cent, respectively. Overall period (2001-02 to 2020-21) indicated area effect i.e. 954.43 per cent for increased production of sorghum, followed by interaction effect, i.e. 3.88 per cent and negative productivity effect i.e. 0.69 per cent, respectively.

During the period-I (2001-02 to 2010-11), area effect was most responsible factor for increased production of sorghum in Nagaur district i.e. 117.02 per cent per annum whereas, interaction effect and negative productivity effect was 43.32 and 60.33 per cent, respectively. During the period-II (2011-12 to 2020-21), productivity effect was 65.87 per cent, negative interaction and positive area effect was 20.02 and 54.15 per cent, respectively. Overall period (2001-02 to 2020-21) indicated area effect i.e. 179.42 per cent for increased production of sorghum followed by interaction effect i.e. -51.01 per cent and negative productivity effect i.e. 28.40 per cent, respectively. Similar results were inconsonance with the results of Sharma (2013) and Baba *et al.* (2019).

For Rajasthan state as a whole, during the period-I (2001-02 to 2010-11), area effect was most responsible factor for increased production of sorghum i.e. 110.03 per cent per annum whereas, interaction effect and negative productivity effect was 18.60 and 28.63 per cent, respectively. During the period-II (2011-12 to 2020-21), negative productivity effect was 155.38 per cent, negative interaction and positive area effect was 78.73 and 334.11 per cent, respectively. Overall period (2001-02 to 2020-21) indicated area effect i.e. 118.77 per cent for increased production of sorghum followed by negative interaction effect and

productivity i.e. 11.41 and 7.37 per cent, respectively. Similar results were found out by Sharma (2013) and Baba *et al.* (2019).

In a nutshell, area effect was most responsible factor for increased production of sorghum in all four districts and Rajasthan state followed by interaction effect (productivity effect + area effect) and productivity effect. Similar results were inconsonance with the results of Sharma (2013) and Baba *et al.* (2019).

CONCLUSION

An analysis of sorghum production in Rajasthan from 2001–02 to 2020–21 revealed significant trends in area, production, and productivity growth across major districts. The area under sorghum cultivation showed a significantly positive growth rate in Ajmer (0.5874% p.a.) and Nagaur (0.2739% p.a.), while it declined in Pali (1.0064% p.a.) and Tonk (1.3724% p.a.). At the state level, the area growth was also significantly negative (0.3524% p.a.). Despite this, production growth remained significantly positive in all districts, with the highest annual growth observed in Tonk (5.1454%) and Ajmer (4.874%). Correspondingly, productivity growth rates were also significantly positive, ranging from 2.906% in Pali to 5.9387% in Tonk, all statistically significant at the 1% level. Decomposition analysis highlighted the area effect as the dominant contributor to increased sorghum output across districts, while the productivity and interaction effects exhibited notable variability. In Ajmer, productivity was the primary driver during Period-I (14.47%), whereas area expansion (250.96%) accounted for most gains in Period-II. Pali saw a major contribution from productivity during Period-II (97.88%), yet the overall increase was largely due to area effect (250.67%). In Tonk and Nagaur, productivity effects were generally negative, with area effects contributing 95.43% and 179.42%, respectively. At the state level, area expansion (118.77%) emerged as the principal factor in production growth, offsetting the negative contributions from productivity (7.37%) and interaction effects (11.41%).

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