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Growth Trends and Productivity Drivers in Sorghum Cultivation: A Comparative Study of Ajmer District and Rajasthan State (2001-2021), India

Narendra Yadav [a++*], Sonu Jain [a#], Sheela Kharkwal [a#], P.S. Shekhawat [a#] and Sumay Malik [a++]

[a] Department of Agricultural Economics, SKN College of Agriculture, SKNAU, Jobner, India.

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

Sorghum is one of the most important cereal crops in the world. It is India's fifth most produced crop after Rice, Wheat, Maize and Pearl millet by marginal and small farmers in semi-arid regions. It is an important source of feed, fodder and bio-fuel apart from food. Due to importance of the crop, the present study examined its trends in area, production and productivity in Ajmer district as well as Rajasthan state.

[++] *M.Sc. Scholar;*
[#] *Assistant Professor;*
**Corresponding author: E-mail: ynarendra0988@gmail.com;*

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Methodology: 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. The study had performed by using two methodology. First is, to calculate, compound annual growth rates in area, production and productivity of sorghum in Ajmer district and Rajasthan state by testing Linear and semi log and exponential function of growth rate. Second is, decomposition analysis, which was used to calculate the proportional impact of area and yield on the change in overall output for the sorghum crop.

Key Findings of the Study: In case of Ajmer district, exponential function for area and semi-log function for production and productivity was best fitted. For Rajasthan state as a whole, exponential function for area and productivity and for production, semi-log function was best fitted. Results revealed that area, production and productivity were significantly positive at 4.31, 12.29 and 11.96 per cent, respectively for Ajmer district. For Rajasthan state as a whole, it was significantly positive at 0.93, 7.02 and 12.55 per cent, respectively. Results were significant at 1per cent level of significance. Decomposition of these trends further showed that growth in sorghum production in Ajmer was 59.60 per cent due to yield effect, followed by 32.86 per cent interaction of yield and area and 7.53 per cent due to area effect alone, while, in Rajasthan state, growth in sorghum production was mainly due to yield effect i.e. 67.97 per cent followed by interaction effect i.e. 37.15 per cent and area effect i.e. -5.12 per cent.

Conclusion: Decline in area along with enhanced productivity might be a good sign for sorghum production for the state, still efforts should be put forth to bring new high yielding varieties of sorghum to take the full advantage from the crop.

Keywords: Sorghum; area; production; productivity; growth trend; decomposition.

1. INTRODUCTION

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 it's 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 (Mundia et al. 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 per cent 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 centennials. They are also used to make syrup and flour and penicillin antibiotic.

2. METHODOLOGY

The study was undertaken in Ajmer district of Rajasthan state. Ajmer district was selected for the study as it has highest area and production under sorghum in the state. Secondary data on area, production and productivity for 20 years i.e. from 2001-02 to 2020-21 were collected from Directorate of Economics and Statistics, Pant Krishi Bhawan, GOR, Jaipur for Ajmer district as well as for Rajasthan state. Then data were analyzed with the help of growth functions i.e. Annual, Semi-log and Exponential function. Three year moving average was applied for area, production and productivity for smoothing the data. The best fit model was used to get the growth rate. The best fit model was selected on the basis of higher R^2 (Coefficient of determination) and low Root Mean Square Error (RMSE) [1,2].

2.1 Compound Annual Growth Rates in Area, Production and Productivity of Sorghum

Linear function:

$$Y = a_0 + a_1 x_1 + \ldots + a_n x_n$$

Where,
Y = Area / production / productivity of Sorghum crop, a_0 = Constant
a_1=Coefficient factor, x_1=Production factor

Semi log function:

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

Where,
Y = Area / production / productivity of Sorghum crop,
α= Constant
β= Regression coefficient, t= time in year
To obtain annual semi- log growth rate, it was computed as follows as
$r = (\beta_1 * 100)$

Exponential function:

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

Taking both side log for linear transformation of this functional model

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

Where,
$Y^* = \log Y$, $\alpha^* = \log \alpha$,
$\beta^* = \log \beta$

Where,
Y= Area / production / productivity of Sorghum crop
α= Constant, β= 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)

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.

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

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

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.

$$P_n - P_o = \Delta P,$$
$$A_n - A_o = \Delta A$$
$$Y_n - Y_o = \Delta Y \quad \ldots(2)$$

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

$$Po + \Delta P = (Ao + A)(Yo + \Delta Y)$$

Hence
$$\frac{Ao\ \Delta Y}{\Delta P} \times 100 + \frac{Yo\ \Delta A}{\Delta P} \times 100 + \frac{\Delta Y\ \Delta A}{\Delta P} \times 100$$

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.

3. RESULTS AND DISCUSSION

3.1 Compound Annual Growth Rates in Area, Production and Productivity of Sorghum

Compound annual growth rates in area, production and productivity of sorghum in Ajmer district: Table 1 and Figs. I, II and III shows the growth rates in area, production and productivity of sorghum in Ajmer district of Rajasthan. Area under sorghum cultivation in Ajmer district was 129137 ha. in 2001-02 and it was 144747 ha. in 2020-21. Results revealed that the growth rate for area was significantly positive i.e. 4.31per cent per annum. Similar results were reported by Jat [3], Hiremath [4], Basavaraja C. Rajur [5] and Kala et al. [6]. Results were in counter to the results of Savitha and Kunnal [7], Kumar et al. [8], Gautam and Singh [9], Daundkar and Pokharkar [10] and Sharma et al. [11]. Production was 59749 MT in 2001-02 and it was 130946 MT in 2020-21. Thus, growth rate for production was significantly positive i.e. 12.29 per cent per annum. Similar results were inconsonance with the results of Jat [3], Hiremath [4], Basavaraja C. Rajur [5], Savitha and Kunnl [7], Gautam and Singh [9], Daundkar & Pokharkar [10] and Kala et al. [6], Sharma et al. [11]. Productivity of sorghum was

463 Kg in 2001-02 and it was 905 Kg in 2020-21. Thus, growth rate for productivity was significantly positive i.e. 11.96 per cent per annum. Similar results were found out by Rakshit et al. [12], Savitha and Kunnal [7], Gautam and Singh [9], Sharma et al. [11]. Thus, growth rates in area, production and productivity was significantly positive at 4.31per cent, 12.29 per cent and 11.96 per cent, respectively. Similar results were found out by Bera et al. [13], Kachroo et al. [14], Ramachandra et al. [15], Ayalew and Sekar [16], Divya and Pathak [17], Laitonjam et al. [18], Nisha et al. [19], Kameriya et al. [20]. Results were in counter to the results of Prabakaran and Sivapragasam [21], Gaware et al. [22] and Parvekar et al. [23].

For Ajmer district, Coefficient of determination (R^2) for area, production and productivity was 0.41, 0.62 and 0.61, respectively. RMSE for area, production and productivity was found to be 0.384, 0.201 and 0.203, respectively.

Table 1. Growth rates in area, production and productivity of sorghum in Ajmer district of Rajasthan

Response variable	Selected Growth Model	Coefficients		R^2	RMSE	Growth rate (% per annum)
		β_0	β_1			
Area 3MA	Exponential	11.74	0.042	0.41	0.039	4.31
Production 3MA	Semi log	10.61	0.050	0.62	0.201	5.03
Productivity 3MA	Semi log	5.69	0.049	0.61	0.204	4.91

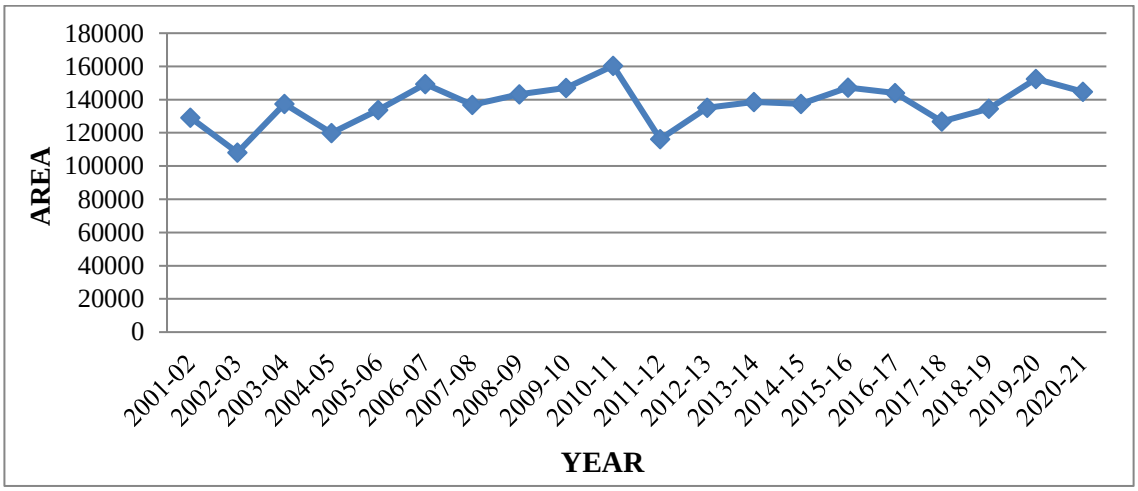

Fig. 1. CAGR in Area of Sorghum crop in Ajmer district from 2001-02 to 2020-21

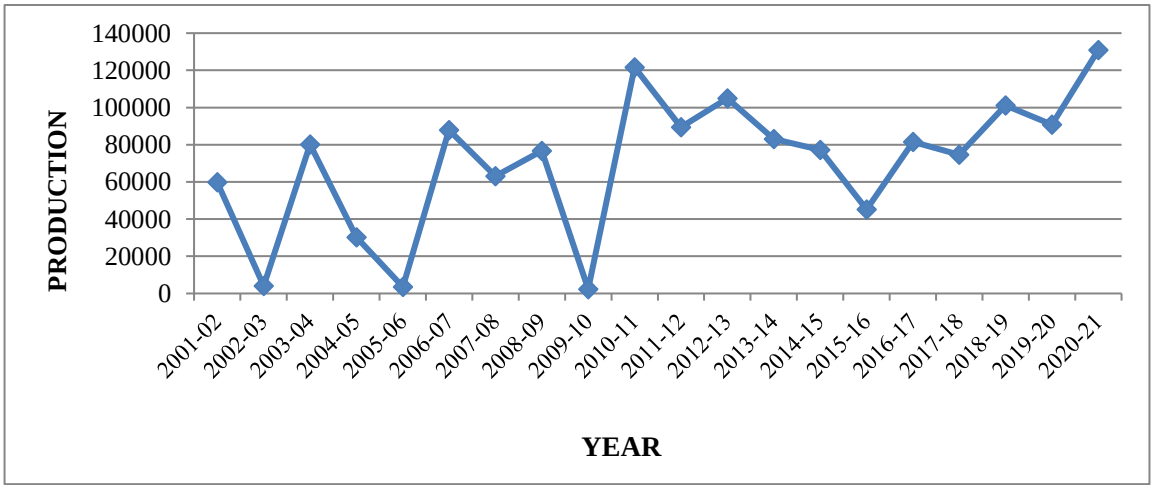

Fig. 2. CAGR in Production of Sorghum in Ajmer district from 2001-02 to 2020-21

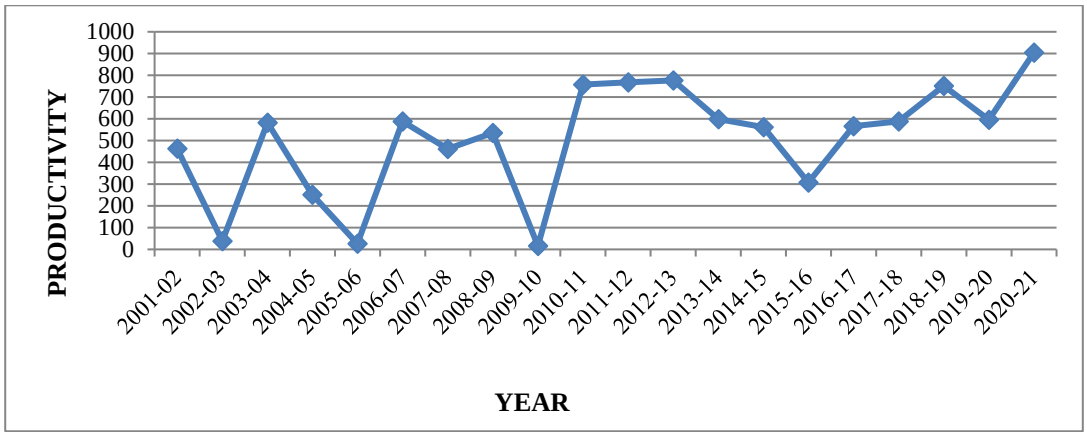

Fig. 3. CAGR in Productivity of Sorghum in Ajmer district from 2001-02 to 2020-21

Compound annual growth rate in area, production and productivity of sorghum in Rajasthan: Table 2 and Fig. IV, V and VI shows the growth rates in area, production and productivity of sorghum in Rajasthan state. Area under sorghum cultivation in Rajasthan state was 614653 ha. in 2001-02 and it was 559686 ha. in 2020-21. Results revealed that the growth rate for area was significantly positive i.e. 0.93 per cent per annum. Similar results were inconsonance with the results of Jat [3], Hiremath [4], Basavaraja C. Rajur [5], Kala et al. [6]. Results were in controversial to the results of Savitha and Kunnal [7], Kumar et al. [8], Gautam and Singh [9], Daundkar and Pokharkar [10] Sharma et al. [11]. Production was 254398 MT in 2001-02 and it was 590340 MT in 2020-21. Thus, growth rate for production was significantly positive i.e. 7.02 per cent per annum. Results were similar with the results of Jat [3], Hiremath [4], Basavaraja C. Rajur [5], Savitha and Kunnal [7], Gautam and Singh [9], Daundkar and Pokharkar [10] and Kala et al. [6], Sharma et al. [11]. Productivity of sorghum was 482 Kg per ha in 2001-02 and it was 1055 Kg per ha in 2020-21. Thus, growth rate for productivity was significantly positive i.e. 12.55 per cent per annum. Similar results were found by Rakshit et al. [12], Savitha and Kunnal [7], Gautam and Singh [9], Sharma et al. [11]. Thus, growth rates in area, production and productivity was significantly positive at 0.93 per cent, 7.02 per cent and 12.55 per cent, respectively. Results were inconsonance with the results of Bera et al. [13], Kachroo et al. and Ramachandra et al. [15], Ayalew and Sekar [16], Divya and Pathak [17], Laitonjam et al. [18] and Nisha et al. [19], Kameriya et al. [20].

For Rajasthan State, Coefficient of determination (R^2) for area, production and productivity was 0.04, 0.66 and 0.50, respectively. RMSE for area, production and productivity was found to be 0.0361, 0.109 and 0.091, respectively.

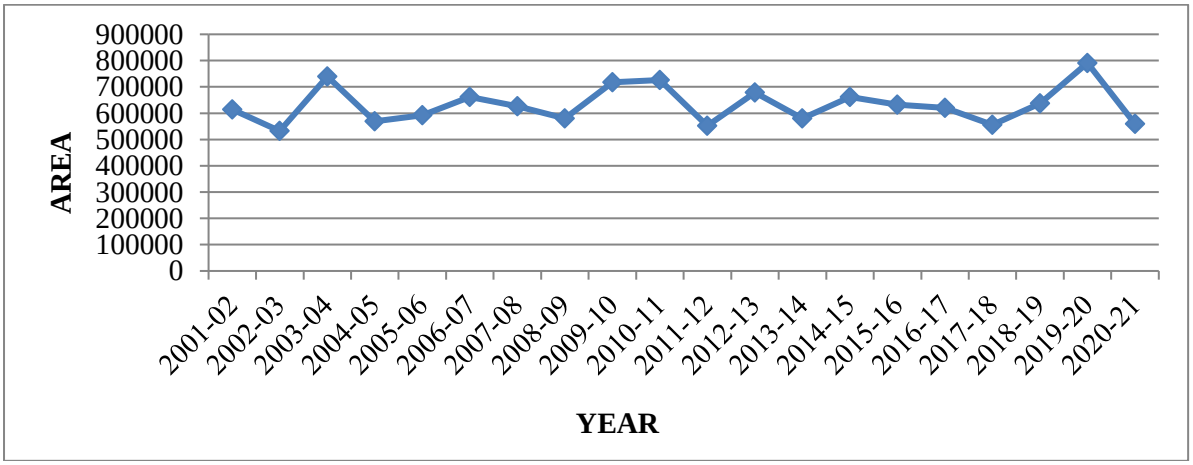

Fig. 4. CAGR in Area of Sorghum in Rajasthan state from 2001-02 to 2020-21

Table 2. Growth rates in area, production and productivity of sorghum in Rajasthan

Response variable	Selected Model	Growth	Coefficients		R^2	RMSE	Growth rate (% per annum)
			β_0	β_1			
Area 3MA	Exponential		13.33	0.009	0.04	0.034	0.93
Production 3MA	Semi log		12.50	0.298	0.66	0.110	2.99
Productivity 3MA	Exponential		6.25	0.11	0.50	0.092	12.56

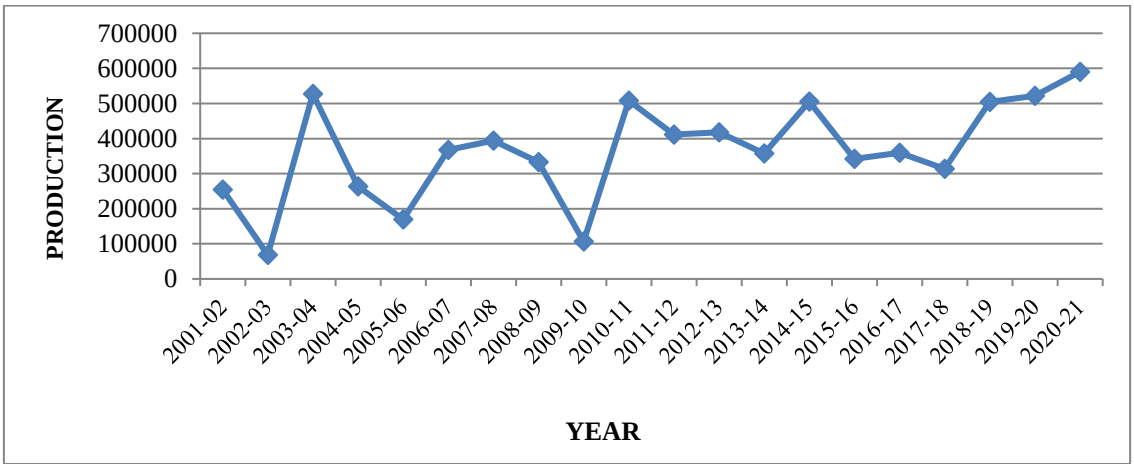

Fig. 5. CAGR in Production of Sorghum in Rajasthan state from 2001-02 to 2020-21

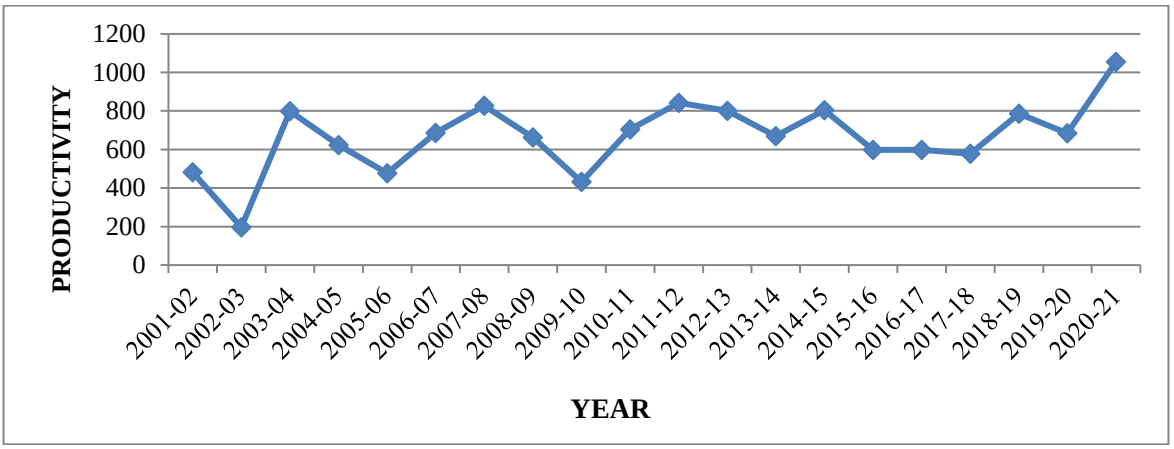

Fig. 6. CAGR in Productivity of Sorghum in Rajasthan state from 2001-02 to 2020-21

Note: - *The production and productivity of sorghum crop was the lowest in Ajmer district as well as Rajasthan state in the year 2009–10, as that year received the least rainfall (375 mm). Chinnasamy et al. [24] support of the result*

3.2 Decomposition Analysis

Table 3 shows the relative contributions of key agricultural production factors in Ajmer district, which had been 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), productivity effect was most responsible factor for increased production of sorghum in Ajmer district *i.e.*53.82 per cent per annum whereas, interaction effect and area effect was 25.77 and 20.39 per cent, respectively. During the period-II (2011-12 to 2020-21), productivity effect was 62.41 per cent, interaction and area effect was 22.31 and 15.27 per cent, respectively. Overall period (2001-02 to 2020-21) indicated productivity effect i.e. 59.60 per cent for increased production of sorghum followed by interaction effect i.e. 32.86 per cent and area effect i.e. 7.53 per cent, respectively. In a nutshell, productivity effect was most responsible factor for increased production of sorghum in Ajmer district followed by interaction effect (productivity effect + area effect) and area effect. Similar results were inconsonance with the results of Sharma [14] and Baba et al. [25].

Table 3. Decomposition analysis of area, productivity and their interaction towards production of sorghum in Ajmer (2001-02 to 2020-21)

District	Period	Year	Productivity Effect %	Area Effect %	Interaction Effect %
Ajmer	I	2001-02 to 2010-11	53.82	20.39	25.77
	II	2011-12 to 2020-21	62.41	15.27	22.31
	Overall	2001-02 to 2020-21	59.60	7.53	32.86

Table 4. Decomposition analysis of area, productivity and their interaction towards production of sorghum Rajasthan (2001-02 to 2020-21)

State	Period	Year	Productivity Effect %	Area Effect %	Interaction Effect %
Rajasthan	I	2001-02 to 2010-11	55.31	21.89	22.80
	II	2011-12 to 2020-21	72.74	3.71	23.55
	Overall	2001-02 to 2020-21	67.97	-5.12	37.15

Table 4 shows the relative contributions of key agricultural production factors in Rajasthan State, which have been 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), productivity effect was most responsible factor for increased production of sorghum in Rajasthan *i.e.*55.30 per cent per annum whereas, interaction effect and area effect was 22.80 and 21.89 per cent, respectively [26]. During the period-II (2011-12 to 2020-21), productivity effect was 72.74 per cent, interaction and area effect was 23.54 and 3.71 per cent, respectively. Here, drastic change was found for area effect from period I (21.89) to period II (3.71). Overall period for Rajasthan (2001-02 to 2020-21), indicate productivity effect (67.96) for increased production of sorghum followed by interaction effect (37.14) but area effect was found negative for Rajasthan in overall period (-5.11), due to drastic change in area effect during the period II. Overall result revealed that productivity effect was most responsible factor for increased production of sorghum in Rajasthan followed by interaction effect (productivity effect + area effect). Similar results were found out by Sharma [27] and Baba et al. [25].

4. CONCLUSION

Ajmer district shows significantly positive growth rates for area, production and productivity *i.e.* 4.31, 12.29 and 11.96 per cent, respectively while, Rajasthan state also shows positive growth rates for area *i.e.* 0.93 per cent, for production and productivity, it was 7.02 and 12.55 per cent, respectively. The decomposition analysis of the growth of the sorghum crop in Ajmer district during the full study period (2001-02 to 2020-21) showed that the area effect (7.53%), yield effect (59.60%), and interaction effect (32.86%) were the key drivers of increase in sorghum production. In Rajasthan, the full study period (2001-01 to 2020-21) showed that the area effect, which accounted negatively for (5.11%) of the growth in sorghum output, and the yield effect (67.96%) and the interaction effect (37.14%) positive for the growth in output.

During the study period from 2001-02 to 2020-21, Rajasthan State show negative growth in area and Ajmer district both show a little bit positive growth in area. While production and productivity show a well growth during this study period for both Ajmer and Rajasthan. Area under sorghum cultivation is decreasing in few districts namely, Pali, Bhilwara, Bharatpur, and Jaipur. This could be achieved by raising the local farmers' awareness of the need to reclaim fallowed land and mobilizing them to do so. A part from this government may offer extension and demonstration services for growing sorghum cultivation.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

I Narendra Yadav, author of the manuscript **"Growth Trends and Productivity Drivers in Sorghum Cultivation: A Comparative Study of Ajmer District and Rajasthan State (2001-2021)|"** declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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