



Evaluating temporal trends and growth dynamics of mustard (*Brassica nigra*) cultivation in Lucknow division of Uttar Pradesh: A two-decade analysis

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Abstract

Mustard (*Brassica nigra*) is a significant oilseed crop in India, and its growth trends significantly impact the economy agriculture, especially in regions like the Lucknow division of Uttar Pradesh (comprising Lakhimpur Kheri, Sitapur, Har-doi, Lucknow, Unnao and Raebareli districts). Future agricultural policies are guided by the analysis of long-term growth rates in area, production, and productivity, which offers important insights into the crop's performance. Time-series data from 2000–01 to 2019–20, divided into two periods (2000–01 to 2009–10 and 2010–11 to 2019–20), are aimed this study. Growth patterns were analyzed using the Compound Growth Rate (C.G.R.) and Linear Growth Rate (L.G.R.) models. The growth patterns of mustard in terms of area, production, and productivity showed an upward trend across the state and both periods. While the area and production demonstrated higher growth rates during period II, productivity growth was highest in period I. Production growth rates consistently exceeded those of area and productivity, with the highest rate observed during period II. Growth rates for productivity and production were statistically significant at 0.05% and 0.01% level of significance, respectively, in both periods, whereas growth rates for area were positive but non-significant same as (Sharma, Agric. Sci. Digest 33:60–62, 2013). The Lucknow division's mustard production has increased significantly, specially during the second period. But, it is important to devote attention to the relatively slower improvement in productivity. In order to maintain and improve growth patterns in the mustard crop, future research should concentrate on determining the factors influencing shower productivity in the division.

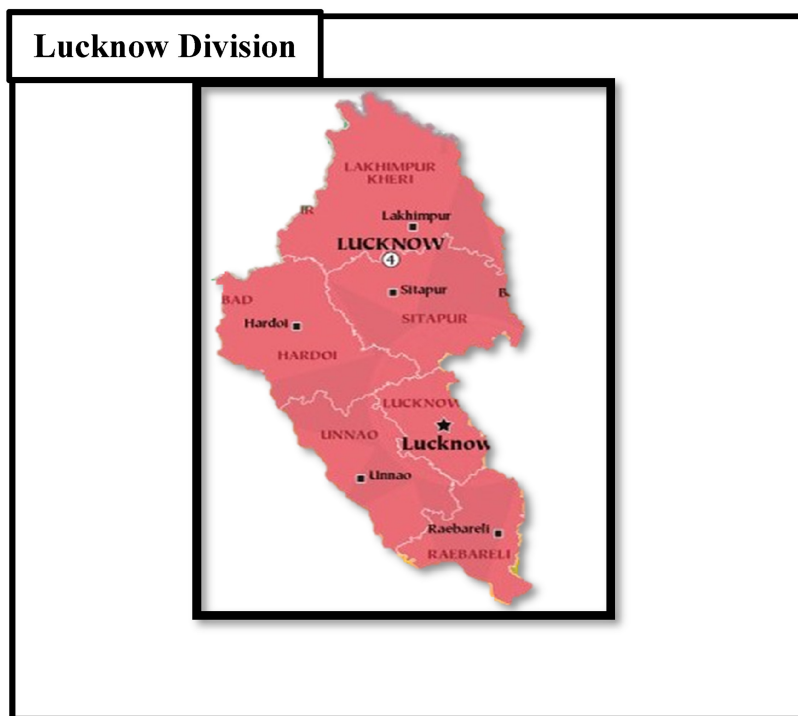
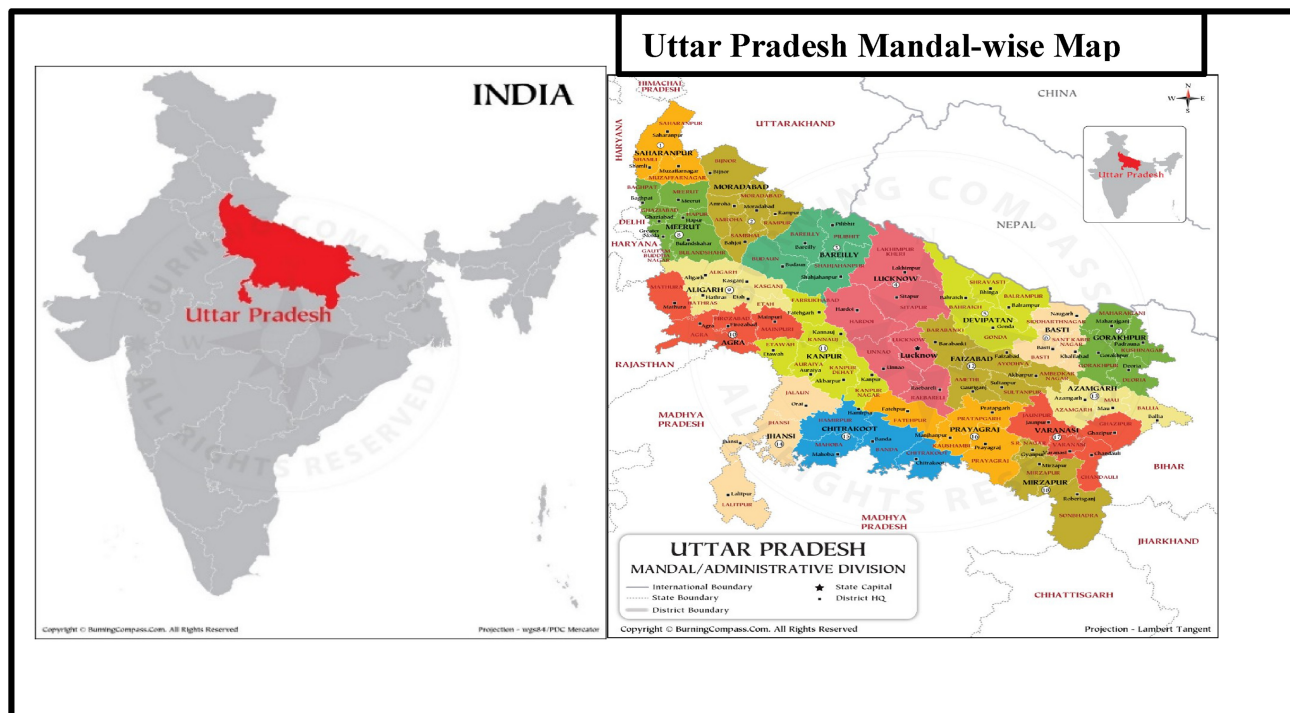
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Graphical Abstract



Keywords Growth rate · Mustard · Periodic analysis · Decomposition · Modelling

Abbreviations

C.G.R. Compound Growth Rate

L.G.R.

Linear Growth Rate

U.P.

Uttar Pradesh



R^2	Determination of Coefficient
CV	Coefficient of Variation
S.P.S.S.	Statistical Package for the Social Sciences
R	R Programming Software
U.S.D.A.	United States Department of Agriculture
MT	Metric Ton
q/ha	Quintals per Hectare
ΔP	Change in Production
ΔA	Change in Area
ΔY	Change in Productivity
A_0	Area in the Base Year
Y_0	Productivity in the Base Year
LGR (%)	Linear Growth Rate in Percent
CGR (%)	Compound Growth Rate in Percent

Introduction

Brassica nigra also called mustard, is a major supplier of vegetables, sauces, edible oils, and animal feed to India's economy. In India, the primary sources of vegetable oil are nine oilseeds. Of these, 39% are soybeans, 26% are groundnuts, and 24% are rapeseed-mustard. These three categories account for almost 88% of the nation's oilseed production. However, when it comes to the nation's output of edible oil, rapeseed-mustard (31%) makes up the largest share, followed by soybeans (26%) and groundnuts (25%). After palm and soybean oil, mustard is the third most crucial oilseed crop grown worldwide. According to U.S.D.A. (USDA Report) data from 2018–2019, it was cultivated on 36.6 million hectares worldwide, productivity 72.4 MT at a productivity of 19.8 q/ha. India has 19.8% of the world's total land and 9.8% of its total production. The third-most significant yearly oilseed crop in India, after groundnuts (9.1 MT) and soybeans (13.6 MT), is rapeseed-mustard (8.3 MT). Rapeseed mustard is widely farmed in India in various agro-climatic conditions, including solo crop/mixed crop, early/late, rainfed/irrigated, and saline or alkaline soils. These conditions are found in North-East, North-West, Central, and Southern states. According to area and production data for 2020–2021, the three states that produce the most mustard are Uttar Pradesh (producing 9.87% on 10.46% area), Madhya Pradesh (producing 12.80% on 11.18% area), and Rajasthan (producing 44.57% of total rapeseed-mustard from 40.55% area). India has Eight kinds of rapeseed-mustard crops: Indian mustard, toria, black mustard, yellow sarson, brown sarson, gobhi sarson, Karan rai, and taramira. Sharma et al. (2013) reported a steady rise in pulse production driven by policies and better practices, though impacted by erratic rainfall and soil fertility issues. Sharma and Joshi (1995) studied rice production in coastal India, noting monsoons and policies influenced acreage, while market and input availability affected stability.

The growth rates of crops were researched by Yoginder and Sharma (1980) during the Green Revolution (period I: 1960–1961–1969–70) and Post-Green Revolution (period II: 1970–71–1978–79) phases. According to the study, there was a more even distribution of growth and higher estimated growth rates in sub-period II than in sub-period I.

By fitting an exponential function, Sharma and Joshi (1994) studied the CGR of Area, production, and Productivity of rice in coastal areas of India. They concluded that, during the kharif season, most districts had negative growth rates for the Area planted to rice. Except for coastal Andhra Pradesh, the kharif season rice production performance in the coastal districts is not particularly outstanding. During the Rabi season, rice acreage grows at a notably positive rate in the majority of the districts. Thus, during the rabi season, a notable increase in rice acreage corresponds to a relatively more significant growth in rice production. Parvekar et al. (2017) studied the growth and instability of sorghum in the Vidarbha region, concluding that while area under cultivation remained relatively stable, yield fluctuations were a key determinant of production instability. An estimate of the increase rate in cashew area, productivity, and production in Kerala from 1952–1953 to 1999–2000 was attempted by Shibu et al. (2004). They separated the entire era into two smaller periods: Period 1st (1952–1953 to 1975–76) and Period 2nd (1976–77 to 1999–2000). They concluded that despite decreased productivity and stagnant production, the area had a increasing growth rate the whole time.

The growth rates of groundnut area, production, and productivity were calculated by Rao & Reddy (2005) for the first and second periods (1988–89 to 2002–03) in the three areas of Andhra Pradesh and also Andhra Pradesh state as a whole. Their research showed that coastal Andhra, Telangana, and the state of Andhra Pradesh had adversely significant compound growth rates of Area and production during the period I. However, in period II, productivity is substantial in coastal Andhra and the State of Andhra Pradesh as a whole; production is significant in all three regions, and the compound growth rate of the Area is significant only in Rayalaseema. Gudmewad et al. (2008) examined the dynamics of area, production, and productivity of oilseed crops in Nanded, India, revealing that while the cultivated area showed variability, production trends followed a steady increase, mainly driven by technological advancements and improved varieties.

The trends in the Area, production, and productivity of the maize crop in Andhra Pradesh between 1969 and 2009 were examined by Rajendra Prasad et al. (2012). For Area and production, the compound function fits the trend the best; for productivity, the S-curve fits the trend the best. The variables influencing the rice crop's output area growth rate sown, irrigated Area under crop, rainfall, fertilizers, quality seeds, land development for cultivation crops, adoption of

soil conservation methods, improved implementation, the extent of computerized cultivation, etc.

In comparing trend Analysis of mustard in Bundelkhand Region, Uttar Pradesh between 1996 to 2019, highlighting that in India and Uttar Pradesh, the area under mustard cultivation has been decreasing, with compound growth rates of -0.2% and -2% per annum, respectively. In contrast, the Bundelkhand region shows a positive growth rate of 4.1% per annum in the area under mustard cultivation by Kalia et al. (2021).

Comprehensive economic analysis of mustard and production trend in Hardoi district of Uttar Pradesh by Verma et al. (2023) this study presents an economic and production trend analysis of mustard cultivation, emphasizing efficient resource allocation and highlighting challenges such as machinery unavailability and weather conditions faced by mustard growers.

Oilseeds and products update (2023) by the United States Department of Agriculture (USDA) this report provides data on rapeseed-mustard crop sowing progress in various Indian states, including Uttar Pradesh, signifying a 6% decrease in area planted compared to the preceding year.

Different districts have varying degrees of growth influence from these sources. Therefore, researchers looking into historical fluctuations in rice crop acreage, production, and productivity would be valuable to managers, scientists, and decision-makers. With the following precise goals in mind, this research efforts to analyse the nature and sources of growth in mustard area, production, and productivity in the Lucknow Division/Mandal of Central Uttar Pradesh:

- To explore the relationship between productivity and Area in relation to the rise in mustard output.
- To assess the growth in mustard production in the Lucknow Division of Central Uttar Pradesh.

Methodology

The State of Uttar Pradesh was broadly divided into twenty Division/Mandal. Data for the period 2000–2001 to 2019–2020 at the district level on Area, production, and productivity of Lucknow division were collected from “Sankhikiya Patrika” by the Government of Uttar Pradesh (UPDES). The present study is based on the time series data of the Area, production, and productivity of mustard for 20 years from 2000–01 to 2019–20 have been used for the present study and all the graphical representation is done by S.P.S.S. software, and calculations are done by R software. Mustard, a significant crop in the state, was taken for this study. The whole period was divided into two sub-periods to assess the impact of new technological innovations.

Period I: 2000–01 to 2009–10.

Period II: 2010–11 to 2019–20.

Estimation of growth rate

Compound Growth Rate (C.G.R.) and Linear Growth Rate (L.G.R.) for the crop characteristics, i.e., area, production, and productivity of mustard crop in Uttar Pradesh State, were estimated by fitting the following functions through period-I, period-II, and whole period. Kalamkar et al. (2002) analyzed growth trends in principal crops in India, finding that while some crops exhibited consistent growth in area and productivity, others faced stagnation due to soil degradation, erratic rainfall, and input cost fluctuations.

Kalia et al. (2021) conducted a comparative trend analysis of mustard in the Bundelkhand region and at the national level. Their findings revealed that mustard production was largely influenced by climatic conditions and government policies, with moderate fluctuations in yield.

Jaypatre et al. (2010) assessed the performance of mango in the South Gujarat region, showing that productivity varied across different seasons due to climatic influences and orchard management practices. The study highlighted the role of improved cultivars and agronomic techniques in stabilizing yields.

Linear function

The equation gives the linear function:

$$Y_t = \alpha + \beta t$$

Where,

t is the time in year, the independent variable.

Y is the trend value of the dependent variable; α and β are constants.

The above equation is fitted by using the least squares method of estimation.

The formula calculates the linear growth rate:

$$\text{Linear growth rate (LGR \%)} = 100 \times \frac{\beta}{y}$$

Compound function

The equation gives the compound function:

$$Y_t = \alpha \cdot \beta^t$$

Or

$$\text{Log } y = \log \alpha + \log \beta$$

Where,

t is the time in year, an independent variable.



Y is the characteristic (Area, production, or productivity of dependent variable).

a and b are constants.

The 'α' and 'β' are calculated by applying the method of Least Squares.

The compound growth rate: $CGR (\%) = \text{antilog}(\beta - 1) \times 100$.

Verma et al. (2024) analyzed the growth rate of the urad (*Vigna mungo*) crop in the Lucknow Division, comparing its trends with state and national levels. The study utilized compound annual growth rate (CAGR) analysis to assess production trends over time. Secondary data from government reports and agricultural surveys were employed, and regression models were used to project future trends and suggest policy measures for sustainable growth.

Measure of instability in mustard production

High growth and low instability in production are requisites for sustainable agricultural performance. It has been a great concern that technological change in mustard production has increased variability, which is one of the essential facts (Gajbhiye S et. al 2010). Since the magnitude of growth and instability in mustard has serious consequences for policy-makers, the level of instability in the Area, production, and productivity has been estimated by using the Cuddy della Valle index, which corrects the coefficient of variations, and it is given by:

$$\text{Instability index} = CV \cdot \sqrt{1 - R^2}$$

where R^2 is the coefficient of determination, and CV is the coefficient of variation.

To measure the effect of change in acreage and productivity on differential production of mustard crop by decomposition analysis

Harkesh et al. (2024) analyzed the growth, decomposition, and instability of major Rabi pulse crops in Madhya Pradesh. Their study found that yield growth contributed significantly to production increases, although area expansion remained a secondary factor. Instability in production was mainly attributed to climate variations and policy interventions.

To study the effect of change in acreage and productivity of mustard on its differential production between two points of time.

Let Y, A, and P be mustard's production, Area, and productivity at a given time. The Y can be stated as:

$$Y = P \cdot A.$$

Let ΔY , ΔA , ΔP be changes in the crop's productivity, Area, and production, respectively, after a specific period.

So, we have

$$\text{Area effect} = \frac{A_0 \Delta Y}{\Delta P} \times 100$$

$$\text{Productivity effect} = \frac{Y_0 \Delta A}{\Delta P} \times 100$$

$$\text{Interaction effect} = \frac{\Delta A \Delta Y}{\Delta P} \times 100$$

A_0 = Area in the base year.

ΔA = Current Area minus the base area.

Y_0 = Productivity in the base year.

ΔY = Current Productivity minus the base productivity.

ΔP = Current production minus base production.

Results and data analysis

The results obtained from the present study, as well as relevant discussion, have been summarized under the following heads:

Percent change in Area, production, and productivity of mustard

The triennium average of Area (in thousand hectares), production (in thousand quintals), and productivity (in q/ha), as well as its percent change for mustard, are shown in Table 1.

The percent change in area, production, and productivity of actual data improved noticeably with 22.77, 46.66, and 19.46 percent during the study period. These figures have shown a positive trend for the mustard crop in the division.

Table 1 Percent change in area, production, and productivity of mustard

Description	% Change in 2019–20 over 2000–01	
	Quinquennium	Triennium
Area	12.27	18.14
Production	45.24	57.81
Productivity	29.20	33.80

% = Percentage

Graphical representation for Area, production, and productivity of mustard crop:

The graphical demonstration for the area, production, and productivity of the mustard crop is shown in Figs. 1, 2, 3.

Area

The area under the mustard crop shows a increasing trend from 2000–01 to 2007–08. The Area has gone down with ups and downs from 2007–08 to 2020–21.

Fig. 1 Area (in Hect.) of mustard in Lucknow Division of Central Uttar Pradesh over the period (2000–01 to 2019–20)

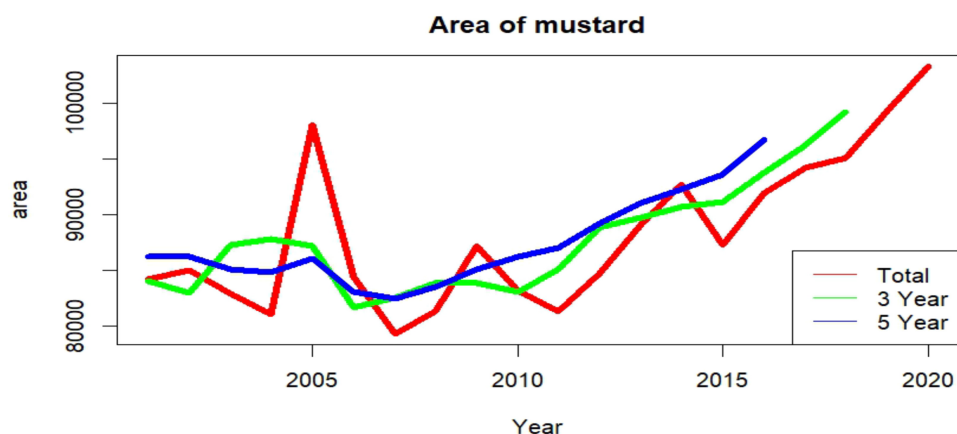


Fig. 2 Production (in quintal) of mustard in Lucknow Division of Central Uttar Pradesh over the period (2000–01 to 2019–20)

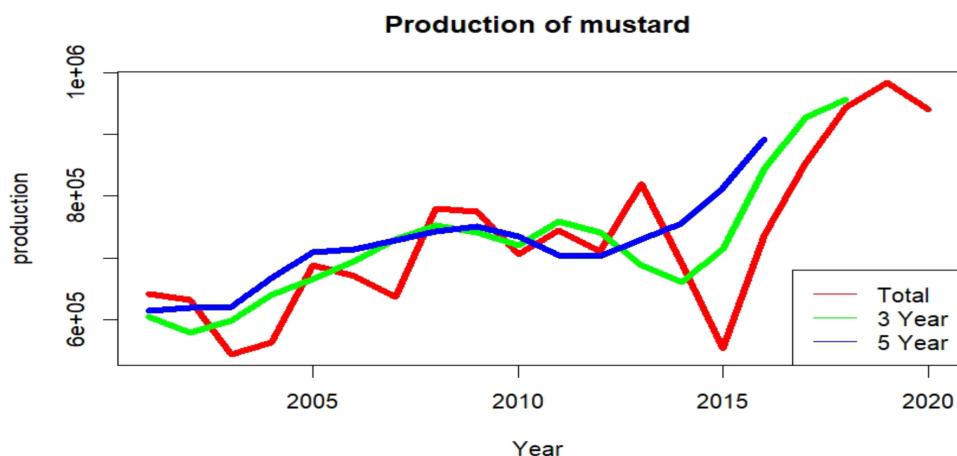


Fig. 3 Productivity (in q/ha) of mustard in Lucknow Division of Central Uttar Pradesh over the period (2000–01 to 2019–20)

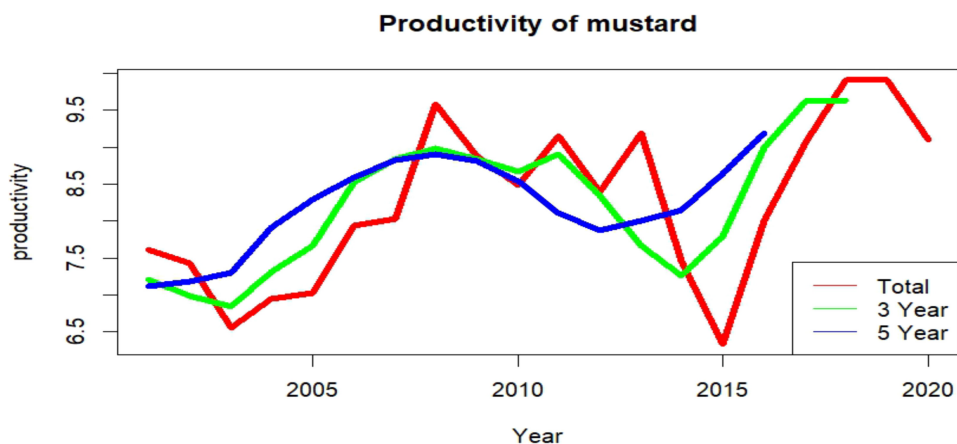


Table 2 Linear Growth Rate and Annual average compound growth rate of Area, production, and productivity of mustard crop in Lucknow Division of Central Uttar Pradesh

Growth Rate(%)	Lucknow Division					
	Area (ha)		Production (q)		Productivity(q/ha)	
	Triennium	Quinquennium	Triennium	Quinquennium	Triennium	Quinquennium
LGR(%)	0.83	0.75	2.15	1.78	1.28	0.97
CGR(%)	0.81	0.74	2.13	1.79	1.29	1.00

q = Quintals, ha = Hectare

Production

Lucknow division accomplished the highest production in the year 2019–20 during the study period, and the positive growth trend of production is visible in Fig. 2.

Productivity

The division accomplished the highest productivity in 2019–20. Figure 3 shows that the productivity of mustard has been increasing, with a trend going back to 2019–20.

The calculated LGR and CGR values for area, production, and productivity are summarized in Table 2, indicating a positive growth rate in mustard cultivation in the division. CV and instability are significant in production, followed by productivity and Area. R^2 is more crucial for productivity, afterward, Area, and production. ($\alpha = 0.05$). The instability percentage for production (10.90%) is slightly higher than that for productivity (10.36%), which indicates that fluctuations in the overall production have a more significant impact compared to fluctuations in productivity. The percentage difference due to instability is around 5.21%, highlighting that production variability is a more prominent factor in the instability.

Linear growth rate and yearly average compound growth rate (%) of Area, production, and productivity of mustard

In veneration of this, the area, production, and productivity of mustard in the division displayed a positive growth rate during the study period from 2000–01 to 2019–20 with 0.83%, 2.16%, and 1.28%, respectively, on the basis of triennium and with 0.75%, 1.78%, and 0.97% on the basis of quinquennium for L.G.R. C.G.R. for Area, production and productivity are 0.80%, 2.12%, and 1.29% respectively on the basis of triennium and 0.73%, 1.78% and 1.00% respectively based on quinquennium. Verma et al. (2023) conducted a comprehensive economic analysis of mustard production trends in Hardoi District, Uttar

Table 3 Measures of instability index (in %) of Area, production, and productivity of mustard

Description	CV (%)	R^2	Instability (%)	Percentage Difference Due to Instability (%)
Area	7.83	0.51	2.49	–
Production	17.48	0.61	10.90	5.21
Productivity	13.17	0.38	10.36	–

Pradesh. The study relied on both primary and secondary data sources, using structured surveys and farmer interviews for cost–benefit analysis. Descriptive statistics, trend analysis, and regression techniques were applied to evaluate production dynamics and identify key economic determinants influencing mustard cultivation. The calculated LGR and CGR values for area, production, and productivity are summarized in Table 2, indicating a positive growth rate in mustard cultivation in the division.

Instability in Area, production, and productivity of mustard crop

High growth and low instability in agricultural production are essential components for sustainable agricultural development. It is desirable that production increases with improved technological in agriculture.

Instability index for Area, production, and productivity is given below in Table 3.

Table 3 indicates that instability in production and productivity needs to be reduced by technological intervention and strengthening of infrastructure- like irrigation systems.

Decomposition analysis

Decomposition analysis demonstrates how variations in productivity and acreage, as well as how they interact, affect mustard crop differential production. The contribution of productivity, area, and their relationship to the variation in production over time is shown in Table 4.

Table 4 Effect of change in acreage and productivity on differential production (in quintals) of the mustard crop in Lucknow Division of Central Uttar Pradesh based on total, triennium, and quinquennium average

Description	Total	Triennium (3 year)	Quinquennium (5 year)
Differential production (ΔP)	299370 (100%)	350126.67 (100%)	277670 (100%)
Area effect ($A \Delta Y$)	124873.87 (41.71%)	204,621.91 (58.44%)	179,195.37 (64.54%)
Productivity effect ($Y \Delta A$)	146065.38 (48.79%)	109,835.10 (31.37%)	75,317.80 (27.12%)
Interaction effect ($\Delta Y \Delta A$)	28,430.75 (9.50%)	37,127.58 (10.60%)	2,198,933 (7.92%)

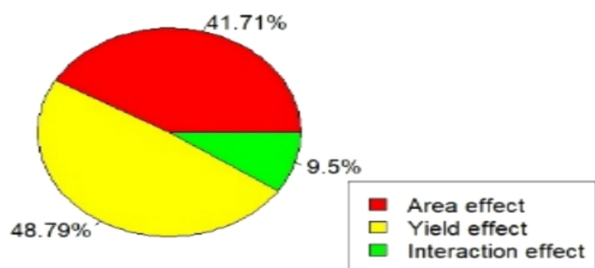


Fig. 4 Decomposition of Total analysis in Lucknow Division of Central Uttar Pradesh over the period (2000–01 to 2019–20)

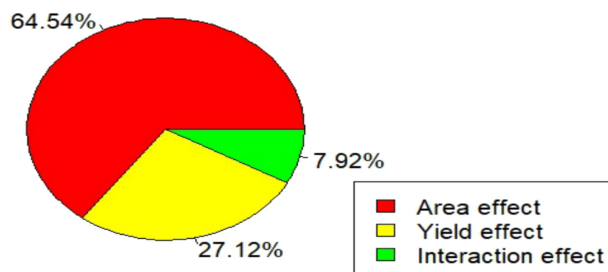


Fig. 6 Decomposition of 5 Year effect in Lucknow Division of Central Uttar Pradesh over the period (2000–01 to 2019–20)

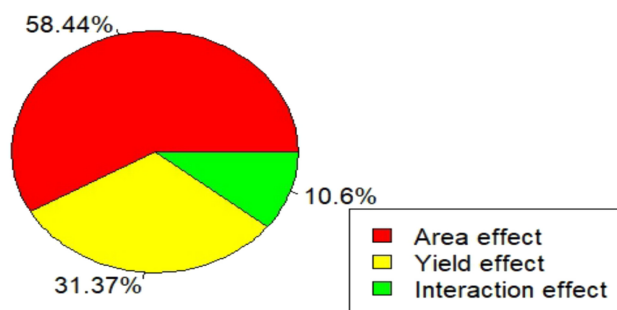


Fig. 5 Decomposition of 3-Year analysis in Lucknow Division of Central Uttar Pradesh over the period (2000–01 to 2019–20)

The variation in production is positive during the study period, indicating that production increased by 350.12 thousand quintals between 2000–01 and 2019–20, with the area effect, productivity effect, and interaction effect contributing 10.60, 58.45, and 31.37 percent, respectively, based on the triennial, and by 277.67 thousand quintals, with the area effect, productivity effect, and interaction effect leading 7.919, 64.54, and 7.92 percent, respectively, based on the quinquennium. The total decomposition analysis of mustard production in the Lucknow Division over the study period (2000-01 to 2019-20) is illustrated in Fig. 4. The short-term (3-year) decomposition analysis provides insights into periodic variations in productivity and area effects (Fig. 5). A broader perspective of mustard production changes using a 5-year decomposition analysis

Table 5 Comparative study of the productivity of mustard crop 2019–20 with different scenarios

Particulars	Average productivity (q/ha)
Lucknow Division	9.90
Central UP	10.67
UP	12.60
Gujarat	19.32
India	13.31

is presented in Fig. 6. A comparative analysis of mustard productivity across different regions is summarized in Table 5, showing how the Lucknow division compares with other regions.

Discussion

The aim of this study was to evaluate the development of mustard cultivation in the Lucknow division of Uttar Pradesh, with an emphasis on production and productivity from 2000 to 2020. In this study, the variables of the linear growth function and compound growth function that is mustard productivity, production, and area under cultivation were fitted to estimate the linear growth rate and compound growth rate. By doing this, the research sought



Table 6 Growth rates in area, production, and productivity of mustard in lucknow division

		LGR	CGR
Area	Period 1	– 0.15 ^{NS}	– 0.15 ^{NS}
	Period 2	2.23**	2.26**
	Combined	0.89**	0.87**
Production	Period 1	2.69*	2.72*
	Period 2	3.77*	3.7*
	Combined	2.19**	2.13**
Productivity	Period 1	2.88*	2.87*
	Period 2	1.42 ^{NS}	1.4 ^{NS}
	Combined	1.25**	1.24**

NS Not Significant, *0.05 Level of significance, **0.01 Level of significance

to have a comprehensive understanding of the patterns of growth in mustard farming in this area.

The results of this study show that during the research period, the Lucknow division's mustard production showed a noticeably upward trend. With LGR and CGR values of 0.92% and 0.91%, respectively, the area planted to mustard exhibited a consistent rise. With LGR and CGR at 2.32% and 2.26%, respectively, production increase was even more visible, indicate that mustard production in the mandal is on a upward trend. The overall growth trend for mustard production in the Lucknow division is shown in Table 6, where productivity changes are analyzed over different periods.

During the period, the Lucknow division's mustard productivity showed an increasing pattern, with LGR and CGR of 1.35% and 1.34%, respectively. The analysis of chickpea production in the Vidarbha region of Maharashtra, as studied by Gajbhiye et al. (2010), indicates significant growth in both cultivated area and total production over the period from 1980–81 to 2007–08. The findings suggest that while production increased, the yield per unit area remained relatively stable, reflecting minimal fluctuations in productivity. This aligns with the current study's observations, where similar trends in crop stability and productivity growth have been recorded. This suggests that increases in yield efficiency were driving up mustard production in addition to the growth in cultivated area. Across the state of Uttar Pradesh, growth rates in production were relatively high, owing to faster increases in both the area under cultivation and productivity. This aligns with a general upward trend in mustard production across the region.

A linear function was shown to offer the best accurate predictions for the area, production, and productivity of mustard in Uttar Pradesh. This conclusion was supported by high R² values, calculations of the coefficient of variation (CV), and an analysis of instability indexes. The study fitted linear functions to data from 2000–2010 to 2011–2020 in

order to calculate LGR and CGR values for these periods. This provided information about the growth patterns within each sub-phase.

A key finding was that both the LGR and CGR for area, production, and productivity remained positive over the entire study phase and across each sub-phase. Notably, the second phase (2011–2020) exhibited the highest rates of increase in both cultivated area and production, whereas the first phase (2000–2010) saw the maximum growth in productivity. However, the second period showed a minor slowdown in productivity, suggesting that although production and area expansion continued. It's interesting to note that LGR values for area, production, and productivity were continuously greater than CGR values during the whole period. This implies that while the growth trend is still beneficial, it can be steadily slowing down. But the main cause of the overall rise in mustard yield is better explained through production development, which was further aided by the ongoing expansion of the area under cultivation. Muthuramu (2019) reviewed structural breaks in time series analysis, demonstrating that major policy changes and external shocks have influenced agricultural trends over time, necessitating refined statistical approaches for accurate forecasting. Meena et al. (2023) studied crop diversification trends in Rajasthan, identifying significant shifts in cropping patterns due to economic factors, irrigation availability, and climate resilience strategies. Their results suggested that farmers are adapting to diversification as a risk mitigation approach. Narayan and Kumar (2015) analysed constraints in the growth of pulse crops in India, finding that limited irrigation facilities, price instability, and inadequate technological adoption were major barriers to increasing pulse productivity.

The analysis specify that the Lucknow mandal's mustard production has experienced remarkable growth in both the area and productivity, especially during the second period of the research period. The discovery demonstrate how much importance technological developments have and supported legislative measures have been in accelerated the growth.

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Author contributions Jogamaya Mohanty: Conceptualization, Investigation, Methodology, editing, Writing-original draft; Piyush Kumar Singh: Supervision; Prabhakar Verma: Writing-review and editing.

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Data availability Data can be made available on request.

Declarations

Conflict of interest The authors declare no conflicts of interest.

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