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COMPOUND GROWTH RATE, TEMPORAL CHANGES, INSTABILITY IN AREA, PRODUCTION AND PRODUCTIVITY AND DECOMPOSITION ANALYSIS OF MAJOR SEED SPICES IN GUJARAT, INDIA

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ABSTRACT

The present investigation was carried out to study the compound growth rate, temporal changes in area, production and productivity, instability in area, production and productivity of major seed spices crops in Gujarat, relative contribution of area and yield towards the changes in total seed spices production. The examination of growth and instability in these parameters was covering the period from 2001-02 to 2022-23 which was further divided into two sub-periods: Period-I (2001-02 to 2011-12), Period-II (2012-13 to 2022-23) and the overall Period-III (2001-02 to 2022-23). The analysis reveals significant growth in area, production and productivity of major seed spices in Gujarat over the study periods. The CGR for the entire comprehensive period exhibited positive growth with the area increasing at a rate of 3.30 per cent per year for cumin, 2.04 per cent for fennel and 19.33 per cent for coriander per year. Coriander and cumin demonstrated remarkable expansion, while fennel showed steady growth, indicating challenges faced in maintaining productivity across these crops. To estimate the instability in area, production and productivity of these seed spices, the Cuddy-Della Valle index was computed for each period. In case of instability of these spices, it can be seen that overall, there is a discernible trend of declining CDV values from Period I to Period II for most parameters in fennel, indicating enhanced stability and consistency in cultivation practices over time. However, coriander consistently demonstrates higher variability compared to fennel and cumin in area, production and productivity. In Gujarat, yield contributed significantly to cumin production with a high impact of 340.80 per cent, while in fennel, area expansion played a dominant role with a contribution of 298.47 per cent. Conversely, in coriander, area expansion was overwhelmingly influential, contributing 10108.24 per cent to production changes.

Key words : Compound Growth Rate, Temporal changes, Instability, Cuddy-Della Valle index.

Introduction

Throughout the annals of mankind's agricultural history, spices stand out as among the most captivating and romanticized crops. In the ancient, misty epochs, when early humans roamed forests in search of sustenance and shelter, they likely experimented with various plants. They would have selected those with aromatic and spicy qualities as particularly valuable, utilizing them to appease their primitive deities and seek protection from the tempestuous forces of nature. From the obscurity of that distant past emerged the foundations of early human civilization. Across all civilizations, aromatic plants held a revered status, often offered as sacred gifts to the divine. Over time, humans likely began harnessing spices and aromatic plants for their presumed medicinal properties, imbuing them with mystical associations and employing them in healing rituals (Ravindran, 2006).

Seed spices serve multiple purposes, not limited to enhancing the flavor and seasoning of food; they are also utilized in various cosmetic, perfumery and pharmaceutical applications. With increasing global health consciousness, there is a growing demand for organically produced seed

spices due to their lack of chemical residues and associated health risks. Key value-added products derived from seed spices include essential oils, oleoresins, spice powders, curry powders and organic seeds. In recent years, there has been a notable shift in export focus towards organic spice products, reflecting the changing preferences and demands of global consumers (Malhotra, 2008).

So, present study entitled was planned with following objectives:

Objectives of the study

(1) To measure the temporal changes in area, production and productivity of major seed spices of Gujarat

(2) To examine instability in area, production and productivity of selected spices crops

(3) To analyse the relative contribution of area and yield towards the changes in total seed spices production

Materials and Methods

Area of study

Gujarat is the leading state in production of seed spice in whole India. It shares 9.127 per cent share of annual spices production of India in the year 2021-22 (Source: Department of Agriculture, Cooperation and Farmers Welfare, GOI) and Gujarat is a major state in export of seed spices in whole world. So, the major seed spices producing districts of Gujarat was selected purposively on basis of their highest triennium average area of cultivation in Gujarat.

Selection of crops

The present study was carried out for major seed spice crops grown in Gujarat. For this study cumin, fennel and coriander crops was selected. Cumin, fennel and coriander was selected based on highest triennium average of area and the data availability of input indices.

Data collection

Secondary data was used to measure the compound growth rate, temporal changes and instability in area, production and productivity of seed spices and decomposition analysis. The growth, temporal changes, instability in area, production and productivity was carried out from the year 2001-02 to 2022-23, which in turn, was split into two periods *viz*., Period-I (2001-02 to 2011-12), Period-II (2012-13 to 2022-23) and overall Period-III (2001-02 to 2022-23).

Analytical procedure

As per the objectives of the study the following different statistical techniques was applied:

Growth rate analysis

Growth rate can be defined as the rate of change per unit time. In the linear form, a straight line is fitted to the yearly data and the parameters are estimated accordingly. On the other hand, the compound growth rate is derived by fitting a straight line to the logarithms of the data and estimating the slope of the line (Acharya *et al.*, 2012).

Compound growth rate

The compound growth rates (CGRs) of seed spices was calculated by using the exponential function of the following specification:

$$Y_t = ab^t u_t \quad (1)$$

Where,

Y_t= Dependent variable (area, production and productivity of seed spices crop in the year 't', export quantity/ export value, *etc.*)

T = Time variable in years taking the value of 1, 2, 3..., n

A = Intercept

B = Regression coefficient

Table 1 : Triennium average of area and production of seed spices in Gujarat(2019-20 to 2021-22)

Crop	Area		Production	
	Area ("00"ha.)	% Share of area	Production ("00"MT)	% Share in production
Cumin	**4209.79**	**62.38**	**3321.04**	**31.71**
Coriander	**1177.50**	**17.45**	**1785.30**	**17.05**
Fennel	**406.54**	**6.02**	**722.33**	**6.90**
Ajwain	165.00	2.44	170.80	1.63
Fenugreek	79.70	1.18	151.00	1.44
Other spices	590.90	8.76	4227.89	40.37
Total spices	6749.10	100.00	10473.00	100.00

Source: Directorate of Agriculture, Department of Agriculture, Farmer's welfare and Cooperation, Gandhinagar. Available at www.dag.Gujarat.gov.in. GOG, 2019-20 to 2021-22.

R = Compound growth rate

u_t = Error term

For the purpose of estimation, the equation expressed in logarithmic form.

$$\text{Log } Y_t = \text{Log a} + t \log b + \log e \quad (2)$$

The value of log b in Equation (6) was computed using the formula,

$$Log\ b = \frac{\left(\Sigma t\, Log\, Y - \left(\Sigma t . \Sigma Log\, Y / N\right)\right)}{\Sigma t^2 - \left(\frac{\Sigma t^2}{N}\right)} \quad (3)$$

Where,

N = Number of years

Subsequently, the compound growth rate (%) was computed using the formulation:

$$\text{Compound growth rate (r)} = [(\text{Antilog of log b}) - 1] \times 100 \quad (4)$$

Student 't' test was used to determine the significance of the growth rates obtained for which the following formulation was employed,

$$t = \text{Log b/ SE (Log b)} \quad (5)$$

$$SE = \sqrt{\frac{\Sigma\left(Y - \bar{Y}\right)^2 - Log\, b * \left(\Sigma\left(Y * t\right) - \Sigma\left(Y\right) * \bar{t}\right)}{\left(N - 2\right)\Sigma\left(Y - \bar{t}\right)^2}} \quad (6)$$

The calculated 't' values, from equation (5) was compared with the table 't' values and the significance was tested at 1 per cent and 5 per cent.

Instability analysis

Instability is the one of the important decision parameters in development dynamics, more so in the context of agriculture production. Substantial fluctuations in crop output not only influence prices leading to sharp fluctuations but also contribute to significant variations in the disposable income of farmers.

The Cuddy-Della Valle index is widely recognized as one of the most commonly used measures of instability for time series data and is universally accepted (Rana *et al*., 2021). The original formulation of the index is given as follows:

$$\text{Instability index (Ix)} = CV\sqrt{\left(1 - \bar{R}^2\right)} \quad (7)$$

$$CV(\%) = \frac{S}{\bar{X}} \times 100 \quad (8)$$

Where,

Ix = Instability index

CV = Coefficient of variation

$\bar{X}$ = Coefficient of multiple determination

S = Mean valueStandard deviation

Decomposition analysis

The relative contribution of area and yield to the total output change (growth) of an individual crop was first estimated by Minhas and Vaidyanathan (1965) using a component analysis model. Sharma (1977) redeveloped the model into the decomposition of output growth of an individual crop. In the present study, relative contribution of area, productivity and their interaction effect to the total output change in the study crops was worked out by two methods *viz*. (i) Simple decomposition model and (ii) Modified decomposition model.

$$\text{Let, } P = A * Y \quad (9)$$

Where,

'P' is the production of seed spices;

'A' is the area under seed spices and

'Y' is the yield of seed spices.

Then, $P_o = A_o * Y_o$ and $Pn = A_n * Y_n$

Accordingly, the simple decomposition model was specified as:

$$P_t - P_o = (Y_t - Y_o)A_o + (A_t - A_o)Y_o + (Y_t - Y_o)(A_t - A_o) \quad (10)$$

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

(Yield effect) (Area effect) (Interaction effect)

Where,

't' refers to current year and '0' refers to base year of the study period.

Thereby, the percentage contribution of each effect was estimated by

$$P = \frac{A_0 \Delta Yt}{\Delta P} \times 100 + \frac{Y_0 \Delta A}{\Delta P} \times 100 + \frac{\Delta Y \Delta At}{\Delta P} \times 100 \quad (11)$$

The triennium average of the start and end of the study period was taken as base year and current year respectively in the simple decomposition model (Equation 11). However, this method has a flaw as it considers only the discrete data and does not take all the years into consideration. Thereby, another method for decomposition analysis suggested by Laitonjam *et al*. (2018) was used in the present study.

The method to be used to rectify the flaw in the model can be called as the Modified Decomposition analysis as given below:

$$P_t - P_o = A_o(Y_t - Y_o) + Y_o(A_t - A_o) + (A_t - A_o)(Y_t - Y_o) \quad (12)$$

$$\Delta P_t = A_o \Delta Y_t + Y_o \Delta A_t + \Delta A_t * \Delta Y_t \quad (13)$$

(Yield effect) (Area effect) (Interaction effect)

Where, P, A and Y represents production, area and yield; '0' and 't' represents time periods such that 't' > '0' by an accounting period which is usually a single year. The result obtained from this method was more reliable as the analysis is done for the continuous data without any omission as the case of simple decomposition model.

This way, the percentage contribution of the effects to the change in total production of an individual crop was arrived by:

$$\frac{A_0 \Delta Yt}{\Delta Pt} \times 100 + \frac{Y_0 \Delta At}{\Delta Pt} \times 100 + \frac{\Delta At * \Delta Yt}{\Delta Pt} \times 100 \quad (14)$$

Change in production (%) = Yield effect + Area effect + Interaction effect

In the present study, the modified decomposition model was used.

Results and Discussion

Temporal changes in area, production and productivity of major seed spices of Gujarat

Temporal variations in area

The area under cumin cultivation has shown a notable increase over the past two study periods. From 189000 hectares in 2001-04, the acreage almost doubled to 374000 hectares in 2010-13, representing an increase of 185000 hectares or a 97.88 per cent rise. This significant growth may be attributed to the subsidies provided by the government through the National Horticultural Mission. However, the increase in the following study period (2019-22) was more modest, rising to 392000 hectares, a change of 18000 hectares or 4.81 per cent. This deceleration in growth may indicate that the expansion potential for cumin has plateaued or that farmers are diversifying into other crops.

Fennel cultivation has also expanded significantly. Starting from 281000 hectares in 2001-04, the area increased by 104000 hectares to 385000 hectares in 2010-13, marking a 37.01 per cent rise. This growth continued robustly into the next study period, reaching 500000 hectares in 2019-22, an increase of 115000 hectares or 29.87 per cent. The consistent increase suggests a strong market demand and possibly better profitability or lower risk associated with fennel cultivation compared to other crops.

The data on coriander cultivation in Gujarat from 2001-02 to 2022-23 reveals significant temporal variations in acreage. In the initial period (2001-2004), coriander was cultivated on a mere 6000 hectares. However, by the study period 2010-2013, this area increased dramatically to 25000 hectares, marking a substantial rise of 19000 hectares. This represents a notable percentage increase of 3.17 per cent over the previous study period. The most significant growth occurred in the period from 2019-2022, where the area under coriander cultivation surged to 143000 hectares, reflecting an extraordinary increase of 118000 hectares from the previous study period. This corresponds to a staggering percentage change of 4.72 per cent. The substantial expansion in coriander acreage over these study periods can be attributed to several factors. The increased demand for coriander, both domestically and internationally, likely played a crucial role. Additionally, coriander might have become an economically attractive crop for farmers due to higher profitability. Government policies and support, such as subsidies and improved agricultural practices, could have further incentivized coriander cultivation. The introduction of better seed varieties and advanced irrigation techniques may have also contributed to higher yields and a larger cultivation area.

Temporal variations in production

The production of cumin has experienced a remarkable increase over the two study periods. During 2001-04, cumin production was recorded at 78600 tonnes. This figure saw a substantial rise to 301300 tonnes in 2010-13, marking an increase of 222700 tonnes or 283.33 per cent. The robust growth during this period can be attributed to the expansion in acreage and possibly enhanced agricultural practices. In the following study period, the growth rate moderated with production reaching 388300 tonnes in 2019-22. This represents an increase of 87000 tonnes or 28.87 per cent, indicating a continued but slower expansion. The deceleration in growth could be due to reaching near-optimal cultivation levels or market saturation.

Fennel production has shown a consistent upward trend. Starting from 37300 tonnes in 2001-04, production increased to 69800 tonnes in 2010-13, reflecting an increase of 32500 tonnes, or 87.13 per cent. This significant rise suggests improved farming practices and favourable market conditions. The growth continued into 2019-22, with production reaching 103100 tonnes, an increase of 33300 tonnes or 47.71 per cent. The sustained growth indicates a strong market demand and possibly better adaptability of fennel to changing agricultural conditions in Gujarat.

Table 2 : Temporal variations in acreage under major seed spice crops in Gujaratfrom 2001-02 to 2022-23.

Crop	Year	Area ('000' ha)	Change in area	Percentage change in area over the previous study period
Cumin	2001-2004	189	-	-
	2010-2013	374	185	97.88
	2019-2022	392	18	4.81
Fennel	2001-2004	281	-	-
	2010-2013	385	104	37.01
	2019-2022	500	115	29.87
Coriander	2001-2004	6	-	-
	2010-2013	25	19	3.17
	2019-2022	143	118	4.72

(Source: National Horticulture Board, 2023).

Table 3 : Temporal variations in production under major seed spice crops inGujarat from 2001-02 to 2022-23.

Crop	Year	Production ('00' tonnes)	Change in production	Percentage change in production over the previous study period
Cumin	2001-2004	786	-	-
	2010-2013	3013	2227	283.33
	2019-2022	3883	870	28.87
Fennel	2001-2004	373	-	-
	2010-2013	698	325	87.13
	2019-2022	1031	333	47.71
Coriander	2001-2004	53	-	-
	2010-2013	433	380	716.98
	2019-2022	212	-221	-51.04

(Source: National Horticulture Board, 2023).

The production data for coriander in Gujarat over the period from 2001-02 to 2022-23 shows significant fluctuations. In the early years (2001-2004), coriander production was relatively low at 5300 tonnes. By the period 2010-2013, production saw a remarkable increase to 43300 tonnes, marking a substantial rise of 38000 tonnes from the previous study period. This translates to an extraordinary percentage increase of 716.98 per cent. However, this trend did not continue into the next study period. From 2019-2022, coriander production dropped to 21200 tonnes, representing a decrease of 22100 tonnes compared to the 2010-2013 period. This decline corresponds to a significant negative percentage change of 51.04 per cent. The sharp increase in coriander production during the 2010-2013 period can be attributed to several factors, including the adoption of improved agricultural practices, the introduction of high-yielding varieties of coriander and possibly favourable climatic conditions. Conversely, the subsequent decline in production from 2019-2022 suggests several potential challenges. The significant reduction in production indicates possible issues related to market demand, pricing and economic viability.

Temporal variations in productivity

The analysis of productivity data for cumin, fennel and coriander over three distinct periods (2001-04, 2010-13 and 2019-22) reveals significant shifts and trends in the yield per hectare of these major seed spice crops in Gujarat. The decadal changes and percentage changes in productivity indicates the variations and underlying factors influencing these trends.

Cumin productivity has shown a notable upward trend over the two study periods. In the period 2001-04, the productivity was 415 kg/ha. By 2010-13, this had increased significantly to 804 kg/ha, representing a rise

of 389 kg/ha or 93.73 per cent. This dramatic improvement can be attributed to advancements in agricultural practices, better seed varieties and possibly more effective pest and disease management. In the subsequent study period, productivity continued to increase, albeit at a slower rate, reaching 992 kg/ha in 2019-22. This increase of 188 kg/ha or 23.38 per cent indicates that while substantial gains were made earlier, further improvements are now more incremental, possibly due to reaching closer to the potential maximum productivity levels for cumin in the region.

Fennel productivity has also seen a consistent increase. From 1333 kg/ha in 2001-04, productivity rose to 1832 kg/ha in 2010-13, an increase of 499 kg/ha or 37.43 per cent. This significant rise suggests improvements in cultivation techniques and favourable growing conditions. By 2019-22, productivity further increased to 2063 kg/ha, marking an additional rise of 231 kg/ha or 12.60 per cent. The slower rate of increase in the most recent study period indicates that productivity gains are becoming more challenging, potentially due to the crop approaching its optimal yield capacity under the current agronomic conditions.

The productivity of coriander in Gujarat has exhibited significant temporal variations from 2001-02 to 2022-23. During the initial period from 2001-2004, the productivity was recorded at 830 kg/ha. This figure dramatically increased in the following study period. From 2010-2013, productivity surged to 1868 kg/ha, representing an impressive increase of 1038 kg/ha. This surge translates to a substantial percentage increase of 125.06 per cent over the previous study period.

However, the subsequent study period saw a decline in productivity. By the period 2019-2022, coriander productivity had decreased to 1508 kg/ha. This represents a decline of 360 kg/ha from the previous period, equating to a negative percentage change of 19.27 per cent. Advancements in irrigation techniques, such as drip irrigation and enhanced nutrient management practices could have contributed to this productivity boost. On the other hand, the decline in productivity from 2019-2022 suggests potential challenges that need to be addressed. These challenges could include adverse weather conditions, pest and disease pressures, soil fertility issues or a lack of access to quality seeds and other inputs.

Annual growth trajectories of acreage, production and productivity

According to Das *et al.* (2016), growth rates are classified as follows: a low growth rate falls between 0 and 5 per cent, a medium growth rate exceeds 5 per cent but does not surpass 10 per cent and a high growth rate is any rate above 10 per cent.

During Period-I (2001-02 to 2011-12), the mean area under cumin cultivation was 261900.09 hectares, with a mean production of 161520.99 tonnes and a productivity of 0.59 tonnes per hectare. The compound growth rate (CGR) for this period was highly significant, with the area expanding at 8.13 per cent per year, production increasing by 17.19 per cent per year and productivity rising by 8.38 per cent per year. In Period-II (2012-13 to 2022-23), the mean area increased to 360777.55 hectares, while the mean production rose to 345862.21 tonnes and productivity improved to 0.96 tonnes per hectare. However, during this period, the CGR for the area showed a significant decline of 0.10 per cent per year, whereas production and productivity continued to grow at rates of 1.29 per cent and 1.19 per cent per year respectively. Considering the overall period from 2001-02 to 2022-23, the mean area under cumin cultivation was 311338.82 hectares, with a mean production of 253691.60 tonnes and a productivity of 0.78 tonnes per hectare. The CGR for the entire period showed positive growth, with the area increasing at 3.30 per cent per year, production at 8.36 per cent per year and productivity at 4.90 per cent per year, all highly significant. Similar results were reported by Dhandhalya *et al*. (2017) for wheat crop in Gujarat and Rohini *et al.* (2018) in cumin in Gujarat.

During Period-I (2001-02 to 2011-12), the mean area under fennel cultivation was 43145.64 hectares with a mean production of 68704.98 tonnes and a productivity of 1.54 tonnes per hectare. The compound growth rates (CGR) for this period were notable with area expanding at 8.82 per cent, production increasing by 12.02 per cent and productivity growing at 2.94 per cent annually, all significant. In Period-II (2012-13 to 2022-23), the mean area slightly decreased to 42996.73 hectares while mean production increased significantly to 89217.96 tonnes, and productivity rose to 2.07 tonnes per hectare. During this period, the area CGR was 5.98 per cent, production CGR was 6.08 per cent and productivity CGR was 0.10 per cent, reflecting sustained growth albeit at a slower pace compared to Period-I. In the overall period (2001-02 to 2022-23), the mean area under fennel cultivation averaged 43071.18 hectares with mean production reaching 78961.47 tonnes and an average productivity of 1.81 tonnes per hectare. The CGR for the entire period showed area increasing by 2.04 per cent, production by 4.56 per cent and productivity by 2.47 per cent annually.

During Period-I, the mean area under coriander cultivation was 13909.36 hectares with a mean production

Table 4 : Temporal variations in productivity under major seed spice crops in Gujarat from 2001-02 to 2022-23.

Crop	Year	Productivity (kg/ha)	Change in productivity	Percentage change in productivity over the previous study period
Cumin	2001-2004	415	-	-
	2010-2013	804	389	93.73
	2019-2022	992	188	23.38
Fennel	2001-2004	1333	-	-
	2010-2013	1832	499	37.43
	2019-2022	2063	231	12.60
Coriander	2001-2004	830	-	-
	2010-2013	1868	1038	125.06
	2019-2022	1508	-360	- 19.27

(Source: National Horticulture Board, 2023).

of 20638.85 tonnes. The mean productivity in this period was 1.37 tonnes per hectare. This period saw impressive growth rates with the Compound Growth Rate (CGR) of area at 22.52 per cent, production at 33.80 per cent and productivity at 9.21 per cent, all statistically significant as indicated by their respective standard errors (SE). In Period-II, the mean area expanded substantially to 94254.82 hectares and the mean production increased to 144590.98 tonnes. The mean productivity also improved to 1.65 tonnes per hectare. The growth rates during this period showed a different trend; the CGR for area was 16.99 per cent, production grew by 13.36 per cent and productivity experienced a negative growth of -2.94 per cent which suggests challenges in maintaining productivity gains despite the increase in area. Over the entire period from 2001-02 to 2022-23, the mean area under coriander cultivation was 54082.09 hectares with mean production at 82614.92 tonnes and mean productivity at 1.51 tonnes per hectare. The overall CGR for area was 19.33 per cent, for production was 22.04 per cent and for productivity was 2.32 per cent, all indicating significant trends supported by their SE values.

Instability in area, production and productivity of selected spices crops

The CDV index offers a nuanced approach by first de-trending the provided series, thereby offering clearer insights into the direction of instability. On the other hand, the use of the coefficient of variation for measuring instability has certain limitations. Notably, in cases where the time series data exhibit a trend, the variation quantified by the CV may be inflated, potentially leading to an overestimation of instability, particularly in regions experiencing consistent production growth. In contrast, the Cuddy Della Valle index helps to address this limitation by detrending the CV using the adjusted coefficient of determination (R^2), thus presenting a more robust measure to capture instability in farm production. The present study categorizes CDV values into three distinct ranges to delineate varying degrees of instability: low instability (ranging from 0 to 15), medium instability (ranging from 15 to 30) and high instability (exceeding 30), as proposed by Sihmar (2014).

Table 5 presents the instability index, measured as the coefficient of variation (CV) and Cuddy Della Valle index (CDV) for acreage, production and productivity of major seed spice crops in Gujarat from 2001-02 to 2022-23. The analysis compares the CV values across different periods and spices to understand the variability in cultivation practices and yield outcomes. The non-significant value of the Cuddy Della Valle index was calculated based on the compound growth rate (Bhopala *et al*., 2023). In cases, where the compound growth rate is non-significant at all probability levels, the Cuddy Della Valle index value is also non-significant. In such instances, the coefficient of variation is used instead of the Cuddy Della Valle index, indicating that the data shows no discernible trend.

The instability indices of acreage, production and productivity of cumin in Gujarat have been analysed using the Cuddy Della Valle Index (CDV) as it had all compound growth rate values highly significant for the periods 2001-02 to 2011-12 (Period-I), 2012-13 to 2022-23 (Period-II), and the overall period from 2001-02 to 2022-23.

During Period-I (2001-02 to 2011-12), the CDV for area was 10.99 per cent, indicating a relatively stable area under cumin cultivation. The production CDV was slightly higher at 11.34 per cent, suggesting moderate variability in production levels. The productivity CDV was

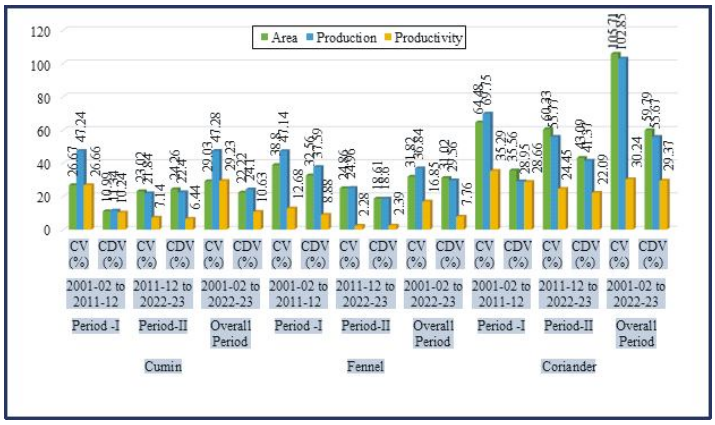

Fig. 1 : Instability Index of acreage, production and productivity of major seed spice crops in Gujarat from 2001-02 to 2022-23.

10.24 per cent, reflecting a fairly consistent yield per hectare. In Period-II (2012-13 to 2022-23), the CDV values show a shift in variability. The CDV for area increased to 24.26 per cent, indicating greater fluctuations in the area dedicated to cumin cultivation. The production CDV was 22.40 per cent, which is higher than the first period but still indicates significant variability in production. Notably, the productivity CDV decreased to 6.44 per cent, demonstrating an improvement in yield stability compared to Period-I. Over the entire period from 2001-02 to 2022-23, area CDV was 22.22 per cent, indicating considerable fluctuations in the cultivated area over the two study periods. The production CDV was 24.10 per cent, showing substantial variability in cumin production. The productivity CDV for the overall period was 10.63 per cent, suggesting a moderate level of consistency in yield despite the fluctuations in area and production. The area and production of cumin in Gujarat have experienced significant variability, the productivity has shown more stability, particularly in the second period. Jhajhria (2015) reported that during the same period, instability in the area, production and yield of cumin in Rajasthan increased likely due to unfavourable weather conditions and a high incidence of pests and diseases.

During Period-I (2001-02 to 2011-12), the CDV values for area, production and productivity were 32.56 per cent, 37.59 per cent and 8.88 per cent respectively in fennel. These values indicate a relatively high variability in area and production whereas productivity exhibited more stability. In Period-II (2012-13 to 2022-23), the CDV values for area, production and productivity decreased to 18.61 per cent, 18.60 per cent and 2.39 per cent respectively. This period shows a marked reduction in variability for area production and productivity suggesting improvements in cultivation practices and stability in production systems. Overall, for the entire period from 2001-02 to 2022-23, the CDV values for fennel in area, production and productivity were 31.02 per cent, 29.56 per cent and 7.76 per cent respectively. These overall values reflect a combination of the high variability observed in Period-I and the reduced variability in Period-II. This reduction in variability can be attributed to the increase in the market demand of fennel due to high prices in markets.

The consistently low values during Period-I (2001-02 to 2011-12) in coriander, the CDV for area, production and productivity were 35.56 per cent, 26.95 per cent and 28.66 per cent, respectively. These values indicate significant variability in all three parameters. In Period-II (2012-13 to 2022-23), the CDV values for area, production and productivity were 43.09 per cent, 41.37 per cent and 22.09 per cent, respectively. Compared to Period-I, these values suggest increment in variability, indicating a more unstable trend in coriander cultivation. However, the variability in area and production remains notable, albeit more pronounced than in the earlier period. In the overall period (2001-02 to 2022-23), the CDV values were 59.79 per cent for area, 55.67 per cent for production and 29.37 per cent for productivity. These values reflect an overall unstabilization trend with increased variability in both production and area. Variability in productivity across all periods suggests that despite fluctuations in area and production, coriander yields have remained relatively stable over the years. Jhajhria (2015) reported similar instability trends in coriander yield in India for the period from 1981-82 to 2009-10, noting a decline in instability. This improvement was mainly attributed to better irrigation facilities, high-quality seeds and improved disease and pest management.

Relative contribution of area and yield towards the changes in total seed spices production

Decomposition analysis is a statistical technique used to break down changes in an aggregate variable into its component parts. Decomposition analysis is a useful statistical method in agricultural economics that breaks down changes in crop production into components attributable to area expansion and productivity changes. This approach helps in understanding the underlying factors contributing to production growth or decline. When interpreting the results of decomposition analysis in agricultural studies, it is imperative to meticulously consider the contextual intricacies. A pronounced contribution from the area expansion signifies that the augmentation in cultivated land has been a pivotal driver of increased production. This phenomenon may stem from factors such as comprehensive land reforms, the transformation of non-agricultural land into arable land

Table 5 : Compound annual growth rates of acreage, production and productivity of major seed spice crops in Gujarat from 2001-02 to 2022-23.

Crop		Interval	Entity	Area	Production	Productivity
Cumin	Period-I	2001-02 to 2011-12	Mean	261900.09	161520.99	0.59
			CGR%	8.13**	17.19**	8.38**
			SE	0.11	0.15	0.13
	Period-II	2012-13 to 2022-23	Mean	360777.55	345862.21	0.96
			CGR%	0.10**	1.29**	1.19**
			SE	0.24	0.21	0.07
	Overall Period	2001-02 to 2022-23	Mean	311338.82	253691.60	0.78
			CGR%	3.30**	8.36**	4.90**
			SE	0.22	0.30	0.15
Fennel	Period-I	2001-02 to 2011-12	Mean	43145.64	68704.98	1.54
			CGR%	8.82**	12.02*	2.94**
			SE	0.32	0.37	0.09
	Period-II	2012-13 to 2022-23	Mean	42996.73	89217.96	2.07
			CGR%	5.98**	6.08**	0.10**
			SE	0.22	0.22	0.02
	Overall Period	2001-02 to 2022-23	Mean	43071.18	78961.47	1.81
			CGR%	2.04**	4.56**	2.47**
			SE	0.33	0.34	0.09
Coriander	Period-I	2001-02 to 2011-12	Mean	13909.36	20638.85	1.37
			CGR%	22.52*	33.80*	9.21**
			SE	0.40	0.48	0.30
	Period-II	2012-13 to 2022-23	Mean	94254.82	144590.98	1.65
			CGR%	16.99	13.36*	-2.94**
			SE	0.56	0.51	0.17
	Overall Period	2001-02 to 2022-23	Mean	54082.09	82614.92	1.51
			CGR%	19.33*	22.04*	2.32**
			SE	0.48	0.54	0.30

Note: 1. ** and * significant at 1 per cent and 5 per cent level. 2. CGR – compound growth rate and SE – standard error.
3. A = area (ha) P = production (metric tonnes) and Y = productivity.

or demographic pressures compelling the utilization of marginal lands. The decomposition analysis was conducted for three periods: Period I (2001-02 to 2011-12), Period II (2012-13 to 2022-23) as well as for the overall period from (2001-02 to 2022-23). Table 6 presents the decomposition of cumin, fennel and coriander production in terms of area, yield and interaction effects.

During Period I, the contribution of area to production changes in cumin was exceptionally high at 312.31 per cent. This indicates that the expansion of cumin cultivation area played a significant role in increasing production during this period. The production increase was notably driven by the yield expansion with a contribution of 229.78 per cent. The interaction effect (-442.09 per cent) contributed negatively to cumin production in Gujarat. Hence, during Period-I, both area and yield effect was found to contribute more to production of cumin in the state. During Period II, the contribution of area to production changes dropped to 69.71 per cent, indicating a reduced emphasis on area expansion compared to Period-I. The yield effect contribution, though still positive at 103.59 per cent, showed a significant decrease, reflecting a shift from extensive to intensive production methods. Negative interaction effect contribution (-73.30 per cent) persisted but was less severe compared to Period-I. Over the entire period, the contribution of area

Table 6 : Instability Index of acreage, production and productivity of major seed.

Crop		Interval	Entities	Area	Production	Productivity
Cumin	Period -I	2001-02 to 2011-12	CV (%)	26.67	47.24	26.66
			CDV (%)	10.99	11.34	10.24
	Period-II	2012-13 to 2022-23	CV (%)	23.02	21.84	7.14
			CDV (%)	24.26	22.40	6.44
	Overall Period	2001-02 to 2022-23	CV (%)	29.03	47.28	29.23
			CDV (%)	22.22	24.10	10.63
Fennel	Period -I	2001-02 to 2011-12	CV (%)	38.80	47.14	12.68
			CDV (%)	32.56	37.59	8.88
	Period-II	2012-13 to 2022-23	CV (%)	24.86	24.96	2.28
			CDV (%)	18.61	18.60	2.39
	Overall Period	2001-02 to 2022-23	CV (%)	31.82	36.84	16.85
			CDV (%)	31.02	29.56	7.76
Coriander	Period -I	2001-02 to 2011-12	CV (%)	64.48	69.75	35.29
			CDV (%)	35.56	28.95	28.66
	Period-II	2012-13 to 2022-23	CV (%)	60.33	55.77	24.45
			CDV (%)	43.09	41.37	22.09
	Overall Period	2001-02 to 2022-23	CV (%)	105.71	102.85	30.24
			CDV (%)	59.79	55.67	29.37

Spice crops in Gujarat from 2001-02 to 2022-23. Note: CV- coefficient of variation (%), CDV – cuddy della valle index

Table 7 : Decomposition analysis of major seed spice crops in Gujarat from2001-02 to 2022-23.

Crop		Interval	Per cent contribution		
			Area	Yield	Interaction
Cumin	Period -I	2001-02 to 2011-12	312.31	229.78	-442.09
	Period-II	2012-13 to 2022-23	69.71	103.59	-73.30
	Overall Period	2001-02 to 2022-23	143.24	340.80	-384.04
Fennel	Period -I	2001-02 to 2011-12	176.54	122.33	-198.87
	Period-II	2012-13 to 2022-23	147.10	102.40	-149.50
	Overall Period	2001-02 to 2022-23	298.47	194.29	-392.77
Coriander	Period -I	2001-02 to 2011-12	707.99	175.39	-783.38
	Period-II	2012-13 to 2022-23	794.17	-23.70	-670.47
	Overall Period	2001-02 to 2022-23	10108.24	-944.81	-9063.43

to production changes stood at 143.24 per cent, indicating that area expansion has been a consistent but diminishing factor. The total yield contribution was significantly high at 340.80 per cent emphasizing the exorbitant effect of yield over time. While, interaction effect contributed negatively to cumin production in Gujarat (-384.04 per cent). Swain *et al.* (2014) reported that from 1992-93 to 2012-13, the yield effect was the primary contributor to changes in the production of spices and condiments in Gujarat. Bairwa *et al.* (2022) also reported similar findings in which production of fenugreek was contributed by spread out in yield effect (91.44%) followed by area effect (62.72%) and interaction effect (-54.16%).

During Period-I (2001-02 to 2011-12), the area effect contributed 176.54 per cent to production changes indicating a significant role in increasing fennel production.

The yield effect was also substantial at 122.33 per cent showing a positive impact on production. However, the interaction effect was negative at -198.87 per cent. In Period-II (2012-13 to 2022-23), the area effect slightly decreased to 147.10 per cent, suggesting a marginal reduction in its influence on production. The yield effect reduced to 102.40 per cent indicating a decremental in yield's contribution to production changes. The interaction effect remained negative at -149.50 per cent, continuing to counterbalance the positive effects of area and yield. In the overall period (2001-02 to 2022-23), the area effect significantly increased to 298.47 per cent, indicating its dominant role in fennel production growth. The yield effect also saw an increase to 194.29 per cent, further emphasizing its importance in enhancing production. However, the interaction effect remained negative at -392.77 per cent. Jain (2014) observed a similar trend in potato production in Madhya Pradesh and India from 1991-92 to 2013-14. He found that the area effect was the most significant factor, contributing 155 per cent to the increase in production.

In coriander, during Period-I (2001-02 to 2011-12), the area effect significantly contributed to production changes with 707.99 per cent, indicating that expansion of the cultivation area was a major driver of production growth. The yield effect during this period contributed 175.39 per cent to production changes showing a positive but lesser impact compared to the area effect. However, the interaction effect was highly negative at -783.38 per cent, suggesting inefficiencies or adverse factors affecting the synergy between area and yield. In Period-II (2012-13 to 2022-23), the area effect further increased to 794.17 per cent emphasizing an even greater reliance on expanding cultivation areas to drive production. Conversely, the yield effect turned negative at -23.70 per cent, indicating that yield improvements were not contributing to production growth and were potentially diminishing. The interaction effect remained significantly negative at -670.47 per cent. In the overall period (2001-02 to 2022-23), the area effect was extraordinarily high at 10108.24 per cent, underscoring the dominant role of area expansion in production changes. However, the yield effect was substantially negative at -944.81 per cent, indicating a continuous decline in yield contribution to production over the years. Similarly, the interaction effect was also negative at -9063.43 per cent. Sethi *et al.* (2022) reported similarly in the case of tomatoes in which production saw a substantial increase of 17089.94 tonnes per year over the period from 1997-98 to 2021-22. This significant rise was primarily driven by the area effect which contributed 83.57 per cent with the yield effect also playing a role contributing 17.47 per cent.

Conclusion

The analysis reveals significant growth in area, production and productivity of major seed spices in Gujarat over the study periods. Coriander and cumin demonstrated remarkable expansion, while fennel showed steady growth, indicating challenges faced in maintaining productivity across these crops. The analysis of CDV values indicates increasing instability in the area and production of cumin, fennel and coriander over the two decades, with notable fluctuations in coriander cultivation. Despite these variabilities, productivity showed relative stability, particularly in cumin and fennel. In decomposition analysis, the total yield contribution was significantly high at 340.80 per cent emphasizing the exorbitant effect of yield in production of cumin in Gujarat. The area effect significantly increased to 298.47 per cent, indicating its dominant role in fennel production growth. In coriander, the area effect was extraordinarily high at 10108.24 per cent, indicating it's dominant role in production changes in Gujarat.

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