Journal of Agricultural Development and Policy, 2025
Volume 35, No. 2, 283-288
https://doi.org/10.63066/23220457.35.2.012

NAAS - 4.34
UGC CARE List Journal

Growth and Instability in Area, Production, and Productivity of Major Seed Spices in Gujarat: A Comparative Analysis Across NHM Phases

Alvin George Sebastian, Baljinder Kaur Sidana and Laishram Priscilla

Department of Economics and Sociology, Punjab Agricultural University, Ludhiana, Punjab

Abstract

The present study examines growth and instability in the area, production, and productivity of major seed spices in Gujarat over a period of three decades, from 1994-95 to 2024-25. For analytical purposes, the study period was divided into three phases: pre-NHM (1994-95 to 2004-05), NHM (2005-06 to 2015-16), and post-NHM (2016-17 to 2024-25), to assess changes in performance across policy regimes associated with the National Horticulture Mission (NHM). Compound annual growth rates were estimated using a log-linear regression model, while instability was measured using the Cuddy-Della Valle Index. The results indicate a significant expansion in area under seed spice cultivation across crops, with annual growth of 5.21 per cent for cumin, 5.45 per cent for fennel, and 17.61 per cent for coriander. Coriander recorded the highest growth, while cumin and fennel exhibited relatively steady and consistent expansion. Productivity growth was moderate, suggesting scope for further technical improvement and more efficient input use. The instability analysis reveals moderate variability in area and production, whereas productivity exhibited notable stabilization in the post-NHM period. Among the crops, fennel and coriander recorded the highest production instability, at 17.32 per cent and 17.00 per cent, respectively, while cumin emerged as the most stable crop in terms of area, production, and productivity.

Keywords: Seed spices, Compound annual growth rate, Instability, Gujarat, National horticulture mission

JEL Classification: Q10, Q12, Q18, O13, O47

Introduction

Agriculture remains the backbone of India's economy, supporting livelihoods, ensuring food and nutritional security, and contributing significantly to export earnings. In recent decades, the sector has experienced a notable transformation driven by technological progress, policy measures, and a shift toward high-value crops. Among these, spices hold a special place because of their economic, nutritional, and medicinal significance. India, often referred to as the "Land of Spices" produces nearly 60 of the 109 spices recognized by the International Organization for Standardization (ISO) and remains the world's largest producer, consumer, and exporter of spices (GOI, 2025). There is no other country in the world that produces as much kind of spices as India produces (Devi Priya and Thyagarajan, 2020).

Within this spice basket, seed spices such as coriander, cumin, fennel, and fenugreek are vital to India's agricultural economy. Mainly cultivated in the arid and semi-arid regions of Rajasthan, Gujarat, and Madhya Pradesh, these crops increase farm income and significantly boost India's export performance (Patel et al., 2025). Seed spices are low-input and short-duration crops, typically taking about 130-140 days to mature during the rabi season (Chaudhary et al., 2023). The country's total spice exports reached nearly Rs.39,994 crore (US$4.72 billion) in FY 2024-25, with seed spices constituting a large part (Spices Board, 2025).

The consistent growth of seed spice exports illustrates both India's comparative advantage and the sector's current relevance. Beyond their culinary use, these crops are increasingly recognized for their nutraceutical, medicinal, and industrial applications, opening new avenues for value-added products such as spice oils, oleoresins, and functional foods (Bairwa et al., 2022). Export destinations now include both traditional customers in Asia and the Middle East, as well as rising markets in North America and Europe, implying the growing global presence of Indian seed spices. Initiatives such as quality certification, organic labeling, and geographical indication (GI) tagging have boosted India's international profile. The industry has the potential for further expansion through the adoption of export promotion policies, the implementation of clean manufacturing technology, and

Corresponding author email: alwingeorge857@gmail.com

compliance with international quality standards (Meena et al., 2019).

Gujarat plays a key role in India's seed spice sector because of its favorable agro-climatic conditions, commercialized farming practices, and strong market connectivity. The state produces major seed spices, including coriander, cumin, fennel, and fenugreek, mostly found in its semi-arid and arid regions, where these crops thrive in low rainfall and light-textured soils. In 2023-24, Gujarat contributed approximately 1.29 million tonnes to the total spice production, establishing itself as the second largest spice-producing state in India after Madhya Pradesh (GOI 2025). Gujarat has built a robust environment for spice processing, grading, and exports, assisted by its accessibility to significant ports like Kandla and Mundra, along with a growing private trade network (Meena et al., 2019).

Despite this strong performance, the productivity of seed spices remains below their potential, with substantial yield gaps between experimental stations and farmers' fields. Area and production of these crops also continue to exhibit considerable instability, driven largely by climatic variability, pest and disease incidence, and fluctuations in market prices (Meena et al., 2024). Given that seed spices are predominantly cultivated in arid and semi-arid regions characterized by fragile agro-ecological conditions, production systems remain highly vulnerable to weather extremes, soil degradation, and resource constraints, which together contribute to uneven growth outcomes over time.

In response to these challenges, the National Horticulture Mission (NHM), launched in 2005, placed emphasis on technological interventions, improved input use, and infrastructure development to enhance productivity and stability in horticultural crops, including spices (Sinha and Sharma, 2022). Assessing long-term trends in growth and instability is therefore important for understanding structural changes in the sector and the extent to which productivity and stability have evolved over time. Against this backdrop, the present study examines growth and instability in the area, production, and productivity of major seed spices, viz., coriander, cumin, fennel, and fenugreek in Gujarat over a thirty-year period spanning the pre-NHM, NHM, and post-NHM phases (1994-95 to 2024-25).

Data Sources and Methodology

The study is based on secondary data from 1994-95 to 2024-25, covering a period of 30 years. The required data on area, production, and productivity of major seed spices such as coriander, cumin, fennel, and fenugreek were collected from the Spices Board of India. The study period was divided into three phases: Pre-NHM (1994-95 to 2004-05), NHM (2005-06 to 2015-16), and Post-NHM (2016-17 to 2024-25) to evaluate the impact of the National Horticulture Mission (NHM).

Analytical Framework

Compound Annual Growth Rate

To measure the rate of growth over time, the Compound Annual Growth Rate **(**CAGR**)** was estimated using an exponential growth function of the form:

$$Y_t = ab^t$$

Log transformation of the above function is

$$\text{In } Y_t = \text{In a} + t\,(\text{In } b)$$
$$\text{In } b = \text{In } (1 + R)$$
$$b = 1 + r$$
$$r = b - 1$$
$$r = [\text{Antilog } (\text{In } b) - 1]$$

The compound growth rates were calculated by using the formula

$$\text{CAGR } (\%) = r \times 100$$

where,

Y_t = area/production/productivity in year t
a = intercept
b = regression coefficient
r = CAGR

The significance of these compound growth rates was tested at 1 per cent, 5 per cent, and 10 per cent levels of significance by using Student's t-test. If the calculated value of 't' was greater than the table value of t', then the growth rate was significant, and vice versa.

Instability Analysis

To assess the variability in area, production, and productivity over time, the Cuddy-Della Valle Instability Index (CDVI) was employed. This index provides a refined measure of instability by adjusting the coefficient of variation for trend effects, and is expressed as:

$$\text{CDVI} = \text{CV} \sqrt{1 - r^2}$$

where,

CV = Coefficient of Variation (%), and

r^2 = Coefficient of determination from the trend regression.

This method removes the influence of time trends from the variability, offering a more accurate picture of fluctuations in agricultural performance.

Results and Discussion

Growth rates in the area, production, and productivity of seed spices from Gujarat

Coriander

During the pre-NHM period, the area under coriander expanded significantly at 11.88 per cent per annum, accompanied by a significant rise in production by almost 10 per cent (Table 1). In contrast, productivity declined by 1.73 per cent annually, indicating that output growth

was driven primarily by area expansion rather than yield improvements. Parmar (2019) also reported a similar growth pattern in area, production, and productivity of coriander during this period in Gujarat.

In the NHM period, coriander recorded the highest growth in area and production, with significant annual increases of 22.81 per cent and 21.36 per cent, respectively. Despite this rapid expansion, productivity continued to decline at 1.15 per cent annually, suggesting that production gains were largely extensive. The sharp rise in area and output during this phase reflects the influence of NHM interventions that incentivized diversification towards high-value crops through improved access to inputs, extension services, and markets. A similar growth pattern in area, production, and productivity of coriander during this period in Gujarat was reported by (Bhimani et al*.,* 2025).

During the post-NHM period, growth moderated considerably. Area and production increased at 10.91 per cent and 9.86 per cent per annum, respectively, while productivity registered a small but significant decline of about 1 per cent, indicating stagnation in yield performance.

Overall, coriander cultivation in Gujarat exhibited strong and sustained growth, with area and production increasing significantly at 17.61 per cent and 20.02 per cent per annum, respectively. Importantly, productivity also recorded a positive and significant growth of 2.06 per cent, suggesting gradual yield improvements over the long run despite short-term declines across sub-periods.

Table 1: Growth in area, production, and productivity of coriander in Gujarat

Period	Area	Production	Productivity
Pre-NHM	11.88**	9.95*	-1.73
NHM	22.81***	21.36***	-1.15
Post- NHM	10.91	9.86	-0.93***
Overall Period	17.61***	20.02***	2.06***

*Note: CAGR in per cent per annum, and *, **, and *** indicate significance at 10 per cent, 5 per cent, and 1 per cent level, respectively*

Cumin

During the pre-NHM period, the area under cumin cultivation expanded significantly at 6.8 per cent per annum, accompanied by a comparable increase in production of about 6.6 per cent (Table 2). Productivity also improved moderately at 1.81 per cent per annum, indicating that production growth during this period was supported not only by area expansion but also by yield improvements.

In the NHM period, the growth in area under cumin moderated to 3.73 per cent per annum, while production increased sharply at 8.16 per cent per annum. Productivity registered a strong rise of 3.80 per cent annually, suggesting that output growth in this phase was largely driven by improvements in yield rather than expansion of cultivated area. This shift reflects the role of NHM interventions that encouraged the adoption of improved varieties and better crop management practices. Similar results were reported by Sinha et al. (2025) for the cumin crop in Gujarat.

During the post-NHM period, cumin cultivation exhibited signs of stagnation. Area and production grew modestly at 3.29 per cent and 3.36 per cent per annum, respectively, while productivity remained almost unchanged at around 0.07 per cent, indicating a near-plateau in yield performance.

Overall, cumin cultivation in Gujarat showed strong long-term growth, with production increasing at 9.21 per cent per annum compared to an area expansion of 5.21 per cent. Productivity also improved steadily at 3.68 per cent per annum, highlighting the sustained contribution of technological progress to cumin production over the study period.

Table 2: Growth in area, production, and productivity of Cumin in Gujarat

Period	Area	Production	Productivity
Pre-NHM	6.8***	6.58**	1.81
NHM	3.73**	8.16***	3.80***
Post NHM	3.29	3.36	0.07
Overall Period	5.21***	9.21***	3.68***

*Note: CAGR in per cent per annum, and *, **, and *** indicate significance at 10 per cent, 5 per cent, and 1 per cent level respectively*

Fennel

During the pre-NHM period, fennel cultivation in Gujarat expanded rapidly. The area under fennel increased by 9.90 per cent per annum, accompanied by a nearly similar rise in production of about 10.12 per cent (Table 3). In contrast, productivity registered only a marginal increase of 0.48 per cent per annum, indicating that output growth during this phase was largely driven by area expansion rather than yield improvements. This expansion reflects growing farmer interest in fennel, supported by rising domestic and export demand, favourable prices, and its suitability as a rabi crop in semi-arid regions, while limited productivity gains suggest continued reliance on traditional varieties and practices.

During the NHM period, fennel cultivation experienced a contraction. The area under the crop declined by 4.75 per cent per annum, and production fell by 3.47 per cent annually. Productivity, however, improved moderately at 1.25 per cent per annum, suggesting that farmers who continued fennel cultivation achieved some yield gains. The decline in area and output points to a shift towards relatively more profitable seed spices such as cumin and coriander, which received

stronger market and policy support during this period.

In the post-NHM period, fennel cultivation rebounded sharply. Area and production increased significantly at 12.89 per cent and 12.77 per cent per annum, respectively, while productivity showed only a negligible increase of 0.05 per cent. This pattern indicates that renewed production growth was again driven mainly by expansion of cultivated area rather than yield improvement.

Overall, fennel cultivation in Gujarat exhibited steady long-term growth. Area expanded at 5.45 per cent per annum, production increased at 7.64 per cent, and productivity improved by 2.08 per cent annually. This suggests that fennel production followed a predominantly extensive growth path, supported by gradual improvements in productivity over time.

Table 3: Growth in area, production, and productivity of fennel in Gujarat

Period	Area	Production	Productivity
Pre-NHM	9.90***	10.12***	0.48
NHM	-4.75	-3.47	1.25
Post- NHM	12.89**	12.77**	0.05
Overall Period	5.45***	7.64***	2.08***

*Note: CAGR in per cent per annum, and *, **, and *** indicate significance at 10 per cent, 5 per cent, and 1 per cent level respectively*

Fenugreek

During the pre-NHM period, fenugreek cultivation in Gujarat expanded moderately. The area under fenugreek increased by 3.06 per cent per annum, while production recorded a modest growth of 1.82 per cent. In contrast, productivity declined by 1.20 per cent per annum, indicating that output growth during this phase was driven mainly by area expansion rather than yield improvements. In the NHM period, fenugreek recorded a marked improvement in performance. The area under cultivation expanded significantly by 3.83 per cent per annum, while production increased sharply at 7.22 per cent annually. Productivity also rose strongly by 3.26 per cent per annum, suggesting that output growth during this phase was largely yield-driven, reflecting greater adoption of improved varieties and better crop management practices.

During the post-NHM period, fenugreek cultivation experienced a contraction. The area under the crop declined by 2.34 per cent per annum, and production fell by 2.72 per cent annually. Productivity also declined by 0.37 per cent, indicating a reversal in both extensive and intensive growth.

Overall, fenugreek cultivation in Gujarat exhibited modest but consistent long-term growth. Area expanded at 1.92 per cent per annum, while production increased at 4 per cent annually. Productivity improved significantly by 2.04 per cent per annum, indicating that long-term growth in fenugreek output was driven primarily by yield improvements rather than expansion of cultivated area.

Table 4: Growth in area, production, and yield of fenugreek in Gujarat

Period	Area	Production	Productivity
Pre-NHM	3.06	1.82	-1.20
NHM	3.83***	7.22**	3.26
Post-NHM	-2.34	-2.72	-0.37**
Overall Period	1.92**	4***	2.04***

*Note: CAGR in per cent per annum, and *, **, and *** indicate significance at 10 per cent, 5 per cent, and 1 per cent level respectively*

Instability in the area, production, and productivity of seed spices from Gujarat

Coriander

The coriander in Gujarat showed variation ranging from low to moderately high levels. Over the entire study period (1994-2024), the instability index for the area under coriander cultivation was calculated at 18.5 per cent (Table 5). The variations in crop area remained fairly stable across all periods, ranging closely between 17.8 and 18.2 per cent. Conversely, production instability peaked during the Pre-NHM period (24.6 %) but saw a significant decline during the NHM years (14.9 %). In case of productivity, the highest instability was observed during the NHM period (13.1%), while the Post-NHM period exhibited remarkable stability with a variation of only 0.5 per cent. Similar findings were reported by (Sinha et al., 2025), who observed that the instability in the coriander cultivation area was generally higher compared to its productivity in Gujarat.

Table 5: Measure of Instability in Area, Production, Productivity of Coriander in Gujarat

(per cent)

Period	Area	Production	Productivity
Pre-NHM	18.2	24.6	7.7
NHM	18.0	14.9	13.1
Post-NHM	17.8	18.2	0.5
Overall Period	18.5	17.0	4.9

Cumin

Cumin cultivation in Gujarat exhibited a low level of instability across all the periods. For the entire study period (1994-2024), the Cuddy Della Valle Index for the area under cumin cultivation was just 5.54 per cent (Table 6). Unlike coriander, the instability of area under cumin cultivation increased over time, from 3.51 per cent in the pre-NHM phase to 12.46 per cent in the post-NHM period, despite remaining continuously in the low instability category. Instability in cumin production over the entire study period was also very

low at 4.72 per cent, with the highest instability recorded in the post-NHM period at 12.37 per cent. Interestingly, yield stability decreased significantly over time; the highest productivity instability was recorded in the Pre-NHM period (6.83%), which decreased to 1.72 per cent in the Post-NHM period.

Table 6: Measure of Instability in Area, Production, Productivity of Cumin in Gujarat

(per cent)

Period	Area	Production	Productivity
Pre-NHM	3.51	8.58	6.83
NHM	6.03	2.26	2.56
Post-NHM	12.46	12.37	1.72
Overall Period	5.54	4.72	1.58

Fennel

Fennel cultivation in Gujarat exhibited low to moderate levels of instability across all the study periods. For the entire study period (1994-2024), Cuddy Della Valle Index for the area under fennel cultivation was calculated at 17.06 per cent (Table 7). An upward trend in instability was observed for the area under fennel cultivation in Gujarat, increasing from 9.51 per cent in the Pre-NHM phase to 14.99 per cent in the Post-NHM period, despite the fact that these different periods often stayed under the low instability category. Instability in fennel production was highest during the NHM period at 16.47 per cent, while the Pre-NHM period was observed to be the most stable period with a variation of 9.14 per cent. Productivity remained the most stable parameter throughout the study period; the highest yield instability was observed during the NHM period (6.17 %), which fell to a negligible 0.52 per cent in the Post-NHM period. Similar findings were reported by (Sinha et al., 2025) who observed that the instability in the fennel cultivation area was generally higher compared to its productivity in Gujarat.

Table 7: Measure of Instability in Area, Production, Productivity of Fennel in Gujarat

(per cent)

Period	Area	Production	Productivity
Pre-NHM	9.51	9.14	6.04
NHM	13.08	16.47	6.17
Post-NHM	14.99	15.36	0.52
Overall Period	17.06	17.32	2.38

Fenugreek

Fenugreek cultivation in Gujarat exhibited stable trends in area, production, and productivity with variation largely contained within the lower limits. Over the entire study period (1994-2024), the instability index for the area under fenugreek cultivation was calculated at 13.77 per cent (Table 8). The study revealed a fluctuating pattern in area instability, which reduced considerably to 4.05 per cent during the NHM period before rising to 14.70 per cent in the post-NHM period. In terms of production, instability exhibited a gradual increase throughout the study periods, starting at 8.58 per cent in the pre-NHM period to 14.73 per cent during the post-NHM period. Instability in productivity reached its maximum during the NHM period at 15.59 but showed a significant decline in the Post-NHM period, stabilizing at a negligible 0.46 per cent.

Table 8: Measure of Instability in Area, Production, Productivity of Fenugreek in Gujarat

(per cent)

Period	Area	Production	Productivity
Pre-NHM	12.25	8.58	11.30
NHM	4.05	12.23	15.59
Post-NHM	14.70	14.73	0.46
Overall Period	13.77	10.86	13.91

Conclusions and Policy Implications

The results indicate that during the NHM period, production of coriander, cumin, and fenugreek increased at a higher rate than in the pre-NHM and post-NHM periods. However, coriander showed greater production instability in the pre-NHM period compared to the NHM and overall periods. For cumin, while production and productivity recorded their highest growth during the NHM phase, the expansion in area was strongest during the pre-NHM period. In contrast, instability in both area and production of cumin was highest in the post-NHM period. Fennel followed a different pattern. Area and production declined during the NHM period but recovered strongly in the post-NHM phase, when both recorded their highest growth. Over the entire study period, instability in the fennel area and production was higher than in the pre-NHM period. Fenugreek also exhibited greater instability in area and production during the post-NHM period compared to earlier phases.

Across crops, instability in productivity declined from the NHM to the post-NHM period, indicating greater yield stability in recent years. In contrast, instability in area remained higher than yield instability for all crops, suggesting that fluctuations in production were mainly driven by changes in cultivated area rather than yield performance. This pattern reflects the strong response of farmers' sowing decisions to market conditions and price movements.

The findings suggest that reducing production instability in seed spices requires measures that limit price-driven acreage fluctuations. Policy efforts should focus on strengthening price stabilization mechanisms such as minimum support prices or price deficiency payment schemes, along with the creation of a market intelligence system to guide farmers' planting decisions. At the same time, recent gains

in yield stability should be maintained through continued investment under the Mission for Integrated Development of Horticulture, particularly in micro-irrigation and climate-resilient varieties, to support long-term stability in the seed spice sector of Gujarat.

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Received: October 10, 2025 Accepted: December 05, 2025