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Dynamics of Growth and Instability in Major Seed Spices of Rajasthan

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Abstract

The present study examines growth and instability in the area, production, and productivity of major seed spices in Rajasthan 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 during the NHM period, with annual growth of 14.36 per cent for cumin, 22.08 per cent for fennel, and 11.73 per cent for fenugreek. Coriander recorded a decline in area and production during the Post-NHM period, with negative growth rates of 6.75 per cent and 4.76 per cent, respectively, indicating a gradual decline in Rajasthan's traditional dominance in coriander cultivation during recent years. Productivity growth was moderate, suggesting scope for further technical improvements and more efficient use of inputs. Instability analysis revealed that production instability remained higher than area and productivity instability across most crops. Fennel recorded the highest production instability (92.9%), whereas fenugreek exhibited comparatively stable productivity with an instability index of 11 per cent during the overall study period. The findings highlight the need for productivity-oriented interventions, climate-resilient technologies, and improved extension support to ensure sustainable growth and stability in Rajasthan's seed spice sector.

Keywords: Seed spices, Compound annual growth rate, Instability, Rajasthan, National Horticulture Mission

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

Introduction

India's rich spice heritage has been the backbone of the country's agricultural economy for centuries. The country produces nearly 75 of the 109 spice varieties recognised by the International Organization for Standardization (ISO), making it the world's largest producer, consumer, and exporter of spices (Ainapur *et al.,* 2025). Among the diverse spices cultivated across the country, seed spices in particular, coriander, cumin, fennel, and fenugreek occupy a position of special agricultural and economic significance. These low-input, short-duration rabi crops, typically maturing in 130-140 days (Chaudhary *et al.,* 2023), are predominantly grown in the arid and semi-arid regions of Rajasthan, Gujarat, and Madhya Pradesh, and together contribute substantially to farm incomes and India's export performance (Patel *et al.,* 2025). The country's total spice exports reached nearly Rs. 39,994 crore (US$ 4.72 billion) in 2024-25, with seed spices forming a significant share (Spices Board, 2025).

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Rajasthan and Gujarat together constitute India's "Seed Spices Bowl," accounting for more than 80 per cent of the country's total seed spice production (Lal 2018). Rajasthan possesses favourable agro-climatic conditions for seed spice cultivation, with its semi-arid climate, low rainfall, and light-textured soils providing a natural advantage for crops such as coriander, cumin, fennel, and fenugreek (Bairwa *et al.,* 2020). Beyond their culinary relevance, seed spices are increasingly valued for their nutraceutical, medicinal, and industrial applications, including spice oils, oleoresins, and functional foods, opening new avenues for value addition and export diversification (Meena *et al.,* 2024). Growing demand from markets in North America, Europe, and the Middle East has further reinforced the sector's strategic importance, with initiatives such as GI tagging, organic certification, and quality standardisation enhancing India's global spice profile (Kumar *et al.,* 2023).

However, despite this robust production base, seed spice cultivation in Rajasthan remains constrained by persistent structural challenges. Productivity continues to lag behind potential, with wide yield gaps between experimental stations and farmers' fields estimated at 23 per cent for cumin in Rajasthan alone (Meena *et al.,* 2022). More significantly, area and production remain highly unstable across years, driven by climatic variability, pest and disease pressure, and price volatility in major mandis. These vulnerabilities are particularly acute in arid agro-ecological systems, where fragile resource conditions amplify the risks of uneven and erratic agricultural performance (Meena *et al.,* 2018).

It is in this context that the National Horticulture Mission (NHM), launched in 2005, assumed critical importance. The Mission sought to promote technological interventions, improve input use efficiency, and strengthen infrastructure for horticultural crops, along with spices, to enhance both productivity and stability. Evidence from across India indicates that the NHM had a measurable positive impact on the growth and stability of horticultural crops in the post-NHM period, though the magnitude varied by crop and region (Aiswarya and Swaminathan, 2025). Thus, a comprehensive assessment of how policy-driven changes translated into improved growth and stability in Rajasthan's seed spice sector remains an important research imperative. The present study addresses this question by examining trends in area, production, and productivity of major seed spices, namely coriander, cumin, fennel, and fenugreek, in Rajasthan over a 30-year period from 1994-95 to 2024-25. The study period is divided into three policy phases: Pre-NHM (1994-95 to 2004-05), NHM (2005-06 to 2015-16), and Post-NHM (2016-17 to 2024-25) to enable a systematic comparative assessment of growth dynamics and production instability across distinct policy regimes.

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:

$$Q_t = \alpha\beta^t \varepsilon_t$$

Log transformation of the above function is

$$Ln\ Q_t = Ln\ \alpha + t\ (Ln\ \beta) + \varepsilon_t$$

$$Ln\ \beta = Ln\ (1 + r)$$

$$\beta = 1 + r$$

$$r = \beta - 1$$

$$r = [\text{Antilog}\ (ln\ \beta) - 1]$$

The compound growth rates were calculated by using the formula

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

where,

Q_t = area/production/productivity in year t

α = intercept

β = 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:

$$CDVI = CV \times \sqrt{(1 - AdjR^2)}$$

where,

CV = Coefficient of Variation (%), and

$AdjR^2$ = 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 Rajasthan

Coriander

During the pre-NHM period, the area under coriander cultivation expanded annually at 1.56 per cent, accompanied by a significant rise in production by 5.73 per cent (Table 1). Productivity also grew by almost 4 per cent annually during this period, indicating productivity-led growth in the pre-NHM period. However, during the NHM period, area expanded substantially by 4.14 per cent, while growth in coriander production slowed to 1.28 per cent, and productivity recorded a negative growth rate of 2.90 per cent. This indicates that an increase in production during the NHM period was area driven rather than productivity driven. In the post-NHM period, both area and production registered negative growth rates of 6.75 per cent and 4.76 per cent, respectively, whereas productivity showed a positive growth of 2.23 per cent. This decline in growth may be attributed to changing cropping patterns and relative profitability of competing rabi crops such as wheat. The findings are consistent with Bairwa *et al.,* (2022), who observed a similar negative growth rate of 5.32 per cent in area and 3.99 per cent in production, but a positive growth of 1.33 per cent in productivity during the post Agri Export Zone period (2005-06 to 2019-20) in Rajasthan.

During the entire study period, the area under coriander declined significantly by 2.38 per cent annually, while production also recorded a marginal negative growth of 0.91 per cent. In contrast, productivity increased significantly by 1.49 per cent, suggesting that improvements in yield partially compensated for the reduction in cultivated area. The findings indicate that in case of coriander productivity gains partially offset the decline in cultivated area.

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

Period	Area	Production	Productivity
Pre-NHM	1.56	5.73*	3.91***
NHM	4.14*	1.28	-2.9
Post- NHM	-6.75	-4.76	2.23**
Overall Period	-2.38***	-0.91	1.49***

*(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

The trends in area, production, and productivity of cumin in Rajasthan across different periods are presented in Table 2. The results indicate that during the pre-NHM period, the area under cumin expanded significantly at an annual growth rate of 9.20 per cent, while production increased by 6.90 per cent. However, productivity declined significantly by 5.62 per cent per annum, suggesting that the increase in production was primarily driven by area expansion rather than improvement in yield. The NHM period showed the highest growth among all the sub-periods, with area and production increasing annually at 14.36 per cent and 19.82 per cent, respectively.

Productivity also registered positive growth of 3.73 per cent, indicating that both expansion in area and improvement in yield contributed to growth in production during this period. In the post-NHM period, growth in cumin slowed considerably, with area and production increasing marginally by 2.80 per cent and 1.45 per cent, respectively, while productivity again registered a negative growth rate of 1.27 per cent. The deceleration in growth during this period may be attributed to erratic rainfall patterns typical of Rajasthan's arid zones, high input costs, and price volatility in major mandis, which together discouraged expansion of cumin cultivation. Similar findings were reported by Bairwa *et al.,* (2020), who observed a growth rate of 21.16 per cent in production and 13.08 per cent in area of cumin in Rajasthan during period II (2005-06 to 2018-19). Their study further highlighted that after the establishment of Agri-Export Zones (AEZ) in 2001, the area and production of cumin expanded drastically in Rajasthan.

During the entire study period, cumin exhibited strong growth in both area and production, registering annual growth rates of 6.00 per cent and 7.84 per cent, respectively. Productivity also increased annually at 2.17 per cent. The findings suggest that cumin emerged as one of the fastest-growing seed spice crops in Rajasthan.

Table 2: Growth in area, production, and productivity of cumin in Rajasthan

Period	Area	Production	Productivity
Pre-NHM	9.2***	6.9	-5.62**
NHM	14.36***	19.82***	3.73
Post NHM	2.8	1.45	-1.27
Overall Period	6***	7.84***	2.17***

*(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

The compound annual growth rates of area, production, and productivity of fennel in Rajasthan during Pre-NHM, NHM, Post-NHM, and the overall period are presented in Table 3. During the pre-NHM period, area and production of fennel registered annual growth rates of 6.53 per cent and 6.36 per cent, respectively. However, growth in productivity remained stagnant at 0.32 per cent, indicating that expansion in area was the primary driver of growth in fennel during this period. The NHM period coincided with remarkable growth in fennel cultivation, area and production increased significantly at 22.08 per cent and 28.08 per cent per annum, respectively. Productivity also registered positive growth of 5.35 per cent, indicating that both expansion in cultivated area and improvements in yield contributed to the sharp rise in production. The remarkable growth of fennel during this period may be attributed to policy incentives under the National Horticulture Mission, which promoted input subsidies, extension services, and market linkages, alongside rising domestic and export demand for fennel that incentivised farmers to expand cultivation.

However, during the post-NHM period, growth in fennel moderated considerably, with area, production, and productivity registering slower growth rates of 1.09 per cent, 1.58 per cent, and 1.14 per cent, respectively. During the entire study period, fennel showed strong and significant growth in both area and production, registering annual growth rates of 9.80 per cent and 12.39 per cent, respectively. Productivity also increased significantly at 2.45 per cent annually. Mhaskey *et al.,* (2021) also reported that the area and production of fennel in Rajasthan grew remarkably by 10.87 per cent and 14.29 per cent in period II (2008-09 to 2017-18). The findings indicate that fennel emerged as one of the rapidly expanding seed spice crops in Rajasthan. However, the slowdown in growth during the post-NHM period suggests the need for sustained technological and institutional support to ensure long-term growth in fennel cultivation.

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

Period	Area	Production	Productivity
Pre-NHM	6.53	6.36	0.32
NHM	22.08**	28.08**	5.35
Post- NHM	1.09	1.58	1.14
Overall Period	9.80***	12.39***	2.45***

*(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, area and production of fenugreek increased annually at 5.52 per cent and 5.67 per cent, respectively, while productivity recorded only meagre growth of 0.14 per cent (Table 4). The nearly identical growth rates of area and production indicate that expansion in production during this period was largely driven by expansion in area rather than improvements in yield. The NHM period marked the highest growth in fenugreek cultivation, with area and production increasing annually at 11.73 per cent and 11.98 per cent, respectively. However, growth in productivity remained negligible at 0.22 per cent, indicating that the impressive growth during this period was primarily driven by area expansion rather than improvements in yield. The tremendous growth during this period may be attributed to improved market opportunities and increasing demand for fenugreek in domestic and export markets. However, the post-NHM period witnessed a reverse trend, with area production and productivity registering negative growth rates of 1.39 per cent, 2.9 per cent, and 1.56 per cent, respectively. This decline may be attributed to climatic variability, rising cultivation costs, and price volatility in fenugreek markets. Meena *et al.,* (2024) also observed a decline in area and production of fenugreek at the national level. Their study further reported that declining market prices after 2015-16 contributed to the contraction in the fenugreek area in major producing regions of India.

During the overall study period, fenugreek recorded positive and significant growth in both area and production, with annual growth rates of 3.30 per cent and 3.60 per cent, respectively, while productivity increased marginally by 0.29 per cent per annum. The findings suggest that long-term growth in fenugreek production in Rajasthan is mainly area-driven, with limited contribution from productivity enhancement. This highlights the need for improved technologies, better extension support, and climate-resilient production practices to sustain future growth in fenugreek cultivation.

Table 4: Growth in area, production, and productivity of fenugreek in Rajasthan

Period	Area	Production	Productivity
Pre-NHM	5.52	5.67	0.14
NHM	11.73***	11.98**	0.22
Post-NHM	-1.39	-2.93	-1.56
Overall Period	3.30***	3.60***	0.29

*(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 Rajasthan

Coriander

The instability indices of area, production, and productivity of coriander in Rajasthan across different periods are presented in Table 5. The results indicate that instability in coriander cultivation in Rajasthan ranged from moderate to high levels across different periods. Instability in area was considerably lower during the NHM period (18.9%) compared to the Pre-NHM (28.5%) and Post-NHM (42.0%) periods, suggesting that policy support under the National Horticulture Mission helped to stabilise cultivated area during this period. Instability in coriander production remained higher than area instability across all periods, suggesting that fluctuations were influenced not only by changes in acreage but also by variability in yield and climatic conditions. The highest production instability was observed during the overall period (40.6%), followed by the Post-NHM period (38.1%), and NHM period (30.5%). The relatively lower instability in production during NHM may be associated with improved input use, technological interventions, and extension support provided under the mission.

In the case of productivity, instability remained comparatively lower than both area and production throughout the study period. The highest instability was recorded during the NHM period (17.5%), while the Post-NHM period exhibited relatively greater stability with an

Table 5: Instability Indices in Area, Production and Productivity of coriander in Rajasthan

(per cent)

Period	Area	Production	Productivity
Pre-NHM	28.5	32.5	9.9
NHM	18.9	30.5	17.5
Post-NHM	42	38.1	4.6
Overall Period	38.6	40.6	15

instability index of only 4.6 per cent. Likewise, Mhaskey *et al.,* (2021) reported instability indices of 20.07 per cent and 22.35 per cent in area and production of coriander in Rajasthan during period II (2008-09 to 2017-18). Their study further reported that instability in Rajasthan during this period was due to low domestic price of coriander, aberrant weather conditions, and high incidence of pests and diseases.

Cumin

Cumin cultivation in Rajasthan exhibited moderate fluctuations in area, production, and productivity across different periods of the study (Table 6). The results indicate that instability in area was highest during the Pre-NHM period (28.8%), followed closely by the NHM period (26.3%), while the Post-NHM period registered comparatively lower instability (14%). The highest instability in production was registered during the pre-NHM period (44.8%), followed by the overall period (41.7%). The higher variability in production may be attributed to cumin's susceptibility to unseasonal rainfall, moisture stress, and wilt disease, which are common constraints affecting cultivation in Rajasthan. Although production instability declined during the NHM (36.7%) and post-NHM (23.6%) periods, cumin production continued to experience considerable fluctuations over time. Instability in productivity also remained relatively high, with the maximum instability observed during the NHM period (25.4%), followed by the overall period (23%). The comparatively lower instability recorded during the post-NHM period (11.4%) indicates some improvement in yield stability during recent years.

Overall, the findings suggest that cumin cultivation in Rajasthan was more vulnerable to production fluctuations during the earlier years of the study period. However, the decline in instability during the NHM and post-NHM period suggests that cumin cultivation gradually became more stable over time, possibly due to better crop management practices and increasing farmer experience in handling production risks. Bairwa *et al.,* (2020) also observed an instability of 17.56 per cent in area, 30 per cent in production, and 26.79 per cent during period II (2005-06 to 2018-19) in Rajasthan.

Fennel

Fennel cultivation in Rajasthan exhibited relatively high levels of instability in area, production, and productivity throughout the study period, with instability values showing a generally increasing trend across the pre-NHM and NHM period (Table 7). Instability in area under fennel remained high during the pre-NHM period (40.2%), which increased further during the NHM period (70.9%). The sharp rise in instability may be associated with rapid expansion of fennel cultivation in response to favourable market prices and increasing global demand during the NHM period. Although instability in area declined during the post-NHM period (43.4%), it continued to remain relatively high throughout the study period.

Instability in production of fennel was exceptionally high throughout the study period and remained higher than both area and productivity. The highest production instability was observed during the NHM period (93.3%), followed closely by the overall period (92.9%). Although production instability declined during the post-NHM period (47.2%), fennel cultivation continued to experience considerable variability in production performance. In the case of productivity, instability was highest during the NHM period (25.7%), while the post-NHM period registered relatively lower instability (10.9%), indicating comparatively stable yield performance in recent years. The findings indicate that fennel was the most unstable spice among the major

Table 6. Instability Indices in Area, Production and Productivity of cumin in Rajasthan

(per cent)

Period	Area	Production	Productivity
Pre-NHM	28.8	44.8	21.6
NHM	26.3	36.7	25.4
Post-NHM	14	23.6	11.4
Overall Period	27.7	41.7	23

Table 7. Instability Indices in Area, Production and Productivity of Fennel in Rajasthan

(per cent)

Period	Area	Production	Productivity
Pre-NHM	40.2	52.6	23.1
NHM	70.9	93.3	25.7
Post-NHM	43.4	47.2	10.9
Overall Period	69.8	92.9	23

seed spices studied, particularly in terms of production. The high level of instability observed during the NHM period suggests that rapid commercialization and expansion of fennel cultivation may have increased exposure to market and climatic risks. Mhaskey *et al.,* (2021) also found an exceptionally high instability in production (89.67%) and area (40.55%) of fennel during period II (2008-09 to 2017-18) in Rajasthan.

Fenugreek

The instability indices of area, production, and productivity of fenugreek in Rajasthan across different periods are presented in Table 8. During the Pre-NHM period, fenugreek registered high instability in both area and production, at 49.7 per cent and 49.5 per cent, respectively. Instability in productivity during this period was comparatively lower at 14.3 per cent, suggesting that output fluctuations were influenced by changes in cultivated area rather than variability in yield. The NHM period recorded a noticeable decline in instability; area instability declined to 33.2 per cent, while production instability reduced to 38.6 per cent, and instability in productivity also declined substantially to 7.5 per cent. The reduction in instability during the NHM phase may be attributed to improved access to inputs, better extension support, and increasing adoption of improved cultivation practices under the National Horticulture Mission. In the Post-NHM period, instability in fenugreek declined further, with area, production, and productivity registering values of 28.3 per cent, 27.4 per cent, and 3.3 per cent, respectively. The sharp decline in productivity instability indicates that yield performance in fenugreek became remarkably stable in recent years, likely reflecting greater adoption of improved varieties and better crop management practices among farmers in Rajasthan. Overall, the findings indicate that instability in fenugreek cultivation gradually declined over time, particularly after the introduction of NHM. Compared to other major seed spices, fenugreek exhibited relatively lower productivity instability, suggesting comparatively stable yield performance under Rajasthan's agro-climatic conditions. Meena *et al.,* (2024) also reported that fenugreek cultivation in India became more stable after 2000 due to increased export demand, adoption of high-yielding varieties, and improved nutrient and crop management practices.

Conclusions and Policy Implications

The findings revealed that the NHM period recorded the highest growth in cumin, fennel, and fenugreek, indicating that policy support under the National Horticulture Mission had a positive and visible impact on seed spice cultivation in Rajasthan. The results further showed that growth in production of coriander, cumin, fennel, and fenugreek was driven mainly by expansion in cultivated area rather than improvement in productivity. Cumin and fennel recorded comparatively higher growth in both area and production, whereas coriander and fenugreek showed slower growth during the Post-NHM period. Productivity of coriander and fenugreek also remained relatively low, indicating persistent yield gaps and production constraints in Rajasthan. The instability analysis indicated that instability in production was higher than area and productivity in most of the crops, reflecting the influence of climatic variability, pest incidence, and market fluctuations on seed spice cultivation. Fennel showed the highest instability, particularly in production, while fenugreek exhibited comparatively stable productivity over the study period. The decline in instability observed during the NHM and Post-NHM periods in coriander, cumin, and fenugreek indicates a gradual improvement in cultivation

Table 8. Instability Indices in Area, Production and Productivity of Fenugreek in Rajasthan

(per cent)

Period	Area	Production	Productivity
Pre-NHM	49.7	49.5	14.3
NHM	33.2	38.6	7.5
Post-NHM	28.3	27.4	3.3
Overall Period	41.4	43	11

practices. Thus, future policy interventions should focus more on improving productivity and reducing production risk rather than expansion in cultivated area alone. Greater emphasis is required on the development and dissemination of drought-tolerant and disease-resistant varieties, particularly in view of increasing climatic uncertainty in Rajasthan. Expansion of micro-irrigation, timely weather-based advisory services, and strengthening of extension support can further improve yield performance and production stability. At the same time, the growing international demand for value-added spice products presents significant opportunities for Rajasthan's seed spice sector. Strengthening quality certification systems, processing infrastructure, and export-oriented value chains can enhance the competitiveness of Indian seed spices in global markets. Sustained technological support, stronger market integration, and climate-resilient production strategies will be essential for ensuring long-term growth and stability in Rajasthan's seed spice sector.

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