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Strategies for boosting productivity and exports of Spices from India

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Abstract: India, often referred to as the "Land of Spices," holds a dominant position in the global spice industry, supported by its diverse climatic conditions favorable for spice cultivation. Despite its prominence, the country's spice production is occasionally disrupted by key economic and climatic factors. This study aims to analyze the growth patterns and instability in the cultivation of major Indian spices—red chili, small cardamom, fenugreek seed, and celery seed—over a 15-year period from 2009–10 to 2023–24. Using analytical tools such as the semi-log model, Compound Annual Growth Rate (CAGR), and the Cuddy-Della Valle Index, the study evaluates trends in area, production, productivity, and exports. The findings reveal a general upward trend across all parameters for the selected spices, with the exception of cardamom, which exhibited a decline in cultivated area. A strong correlation was observed between production and exports. Nevertheless, considerable instability was noted across most spices in terms of area, production, productivity, and export. These findings highlight the need for targeted policy interventions aimed at minimizing volatility and enhancing the stability and sustainability of spice production to reduce dependence on imports and ensure self-sufficiency in the sector.

Keywords: *Correlation, Exports, Growth rate, Instability, Production, Productivity.*

1. Introduction

In the global market, spices are a low-volume, high-value commodity [1]. It can be defined as a plant that enhances food, beverages, and other products with flavor, scent, aesthetic appeal, and medicinal benefit [2]. Spices contain a variety of natural compounds with numerous therapeutic benefits and immune-boosting effects [3]. Although there is currently no treatment for COVID-19, foods and spices are crucial in boosting individuals' resistance to the pandemic [4]. According to Mr. Ramkumar Menon, Chairman of the World Spice Organisation (WSO), India is the world's largest producer and exporter of a diverse range of spices. Despite this prominent position, India's share in the global seasoning market, valued at $14 billion in 2024, remains only 0.7%, which is considerably lower than China's 12% and the USA's 11%. At present, India exports 1.5 million tons of various spices worth $4.5 billion, accounting for approximately one-quarter of the total global spice market, which is estimated to be valued at $20 billion [5]. India's food system has traditionally been dominated by spices, with nearly 109 different types commonly used across the country. In FY 2023-24, the export of spices and spice products reached a record high, totaling 4.46 billion USD [6] According to Mr. Menon, value-added products accounted for only 48% of India's spice exports, with the majority being exported as whole culinary spices. Additionally, approximately 85% of the spices cultivated in India are consumed within the domestic market. Although India leads the world in spice production, Vietnam, Indonesia, Brazil and China are also active players in the global spice markets India's rapidly expanding population, shifting consumption habits, and the variety of ways that spices are used in various dishes have all contributed to

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the country's continually increasing need for spices [7]. Although spice production and cultivation area are increasing to meet the annual demand, India is projected to spend approximately Rs. 1,201,568 lakhs on spice imports from foreign countries during 2023-24 [8]. So, it is essential to increase the domestic spice production in the coming years to reduce dependence on imports. By focusing on self-sufficiency rather than relying on imports, the government can develop effective production and trade policies that better balance supply and demand within the domestic market. Moreover, this approach will provide planners and policymakers with valuable insights and practical experience, enabling them to formulate strategies that enhance the stability and growth of India's spice production in the future.

Various researchers have undertaken studies to advance spice cultivation, revealing that spices yield higher profitability compared to other competing crops [9]. Furthermore, Afrad and Akter examined the relationship between growers' knowledge and various socio-economic factors [10]. Islam et al. investigated the efficiency of various spices and concluded that effective management practices can substantially enhance their productivity [3]. Multiple studies have analyzed the growth patterns, trends, and fluctuations in spice production domestically and globally. Singh, et al. [11] and Meena, et al. [12] conducted analyses of the growth and trends in the area, production, and yield of India's principal spices. Similarly Joshi and Singh [1] and Kumawat and Meena [13] authors have studied the growth and volatility of spice production in India. As a leading exporter, India continues to dominate the global market for a wide range of spices [14]. India possesses inherent natural comparative advantages in the cultivation and utilization of spices. These include its diverse agro-climatic zones that support the growth of countless varieties and cultivars of spices, each well-suited to different environmental conditions. Additionally, India benefits from an abundant supply of affordable labor, a vast domestic market, and a rich cultural heritage that deeply integrates spices into cuisine, traditional medicine, and cosmetics. Renowned as the "land of spices," India holds immense potential to satisfy and expand its role in meeting the growing global demand for spices [15]. A comprehensive study of the growth patterns and volatility in the production, export, and regional distribution of Indian spices is essential to understand the sector's dynamics fully. Such analysis will help identify key factors influencing supply and demand, assess market trends, and address challenges related to production variability and export fluctuations. This insight is crucial for formulating effective policies and strategic interventions that can enhance the stability, competitiveness, and sustainable growth of India's spice industry in both domestic and global markets. The country's capacity for sustainable production and exports is indicated by its high growth and low instability rating. This was taken into consideration when planning the current study.

2. Material and Methods

2.1. Data Sources

The present study was based on secondary time series data for the period of 15 years, from 2009-10 to 2023-24. The required data pertained to production, productivity, area and export of chili (red and dried chili), small cardamom, fenugreek seed and celery seed were collected from the FAO website and yearbook of agricultural statistics.

The selection of crops was done by preparing a matrix having four measures which are, high volume, high value, low volume and low value and also consider the availability of the data. According to the given matrix the crops are as follows: -

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Table 1.
Selection of Crops. (Volume in Tonnes & Value in Rs. Lakhs).

	High Value	**Low Value**
High Volume	Red Chilli	Fenugreek seed
	Volume- 5,57,138	Volume- 32,402
	Value- ₹ 8,58,138	Value- ₹ 26,286
Low Volume	Small Cardamom	Celery seed
	Volume-10,571	Volume-7,579
	Value- ₹ 1,37,567	Value- ₹ 9,854

Source: Spice Board

2.2. Trend and Growth Rate Analysis

In numerous research, the semi-log trend function has been frequently employed to estimate the growth rate of area, production, and productivity [13, 16]. The output of a given year in the semi-log function is dependent on the year before it. In this investigation, the well-known compound interest formula was used with equation number (1) [17].

$$Y_t = Y_0(1 + r)t \quad (1)$$

Y_t = Quantity of spice produced/productivity/area in year t.
Y_0 = The quantity of spice produced/productivity/area in the base year
r = Compound growth rate
t = Time in chronological years.
Using the Logarithmic equation (1), the compound growth rate was derived as below,

$$\text{Ln } y = \ln a + t \ln b \quad (2)$$

Then the per cent compound annual growth rate (r) was derived using the relationship,
CAGR (r) = [Antilog (log b) -1] ×100
Using the student's 't' test for the significance of the regression coefficient.

2.3. Instability Analysis

One of the key determinants of development dynamics, and particularly so when it comes to agricultural productivity, is instability. Production instability impacts consumers and price stability, making low-income households more susceptible to market fluctuations [18]. Sustainable development aims for high growth and low volatility [1]. Crop instability is influenced by factors such as improved diversity, nature, economic conditions, weather sensitivity, input availability, and production technology. By using the formula, the coefficient of variation may be utilized to examine the instability of various spice crops in Bangladesh with regard to production, productivity, and area [13, 19].

$$\text{Coefficient of variation} = \frac{\sigma}{\bar{x}} * 100$$

Where,

σ = Standard deviation of variables concerned
$\bar{x}$ = Mean value of the variable.

However, the simple coefficient of variation does not adequately capture the variability in time series data [20]. Therefore, this study employs the coefficient of variation around the trend (CVt), as proposed by Cuddy and Valle [21]. Thus, the equation is as follows,

$$\text{CDVI} = \text{CV} * (1 - R^2)^{0.5}$$

Cuddly- Della Vella Index is worked by multiplying Coefficient of variation with the square root of the difference between unity and adjusted R^2 in the cases where R^2 is significant.

3. Results

The trend and instability in the area, production, productivity, and export of red chilli, small cardamom, fenugreek seed, and celery seed over a fifteen-year period were analyzed using the Compound Annual Growth Rate (CAGR) and the Cuddy Della Vella Index.

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3.1. Trend and Growth Rates in Area, Production and Productivity of Red Chili in India

Globally, chillies are grown as vegetables and spices with some therapeutic properties to cure diabetes, heart disease, cancer, coughing, asthma, toothaches, and sore throats [22]. In India, chilli is among the most extensively cultivated spice crops. The leading chilli-producing states include Karnataka, Odisha, Maharashtra, Madhya Pradesh, West Bengal, Tamil Nadu, and Andhra Pradesh [20]. In India, chilli is cultivated on an average area of approximately 0.41 million ha with a total production of around 4.5 million tons. The average productivity is about 2.00 tons per hectare. In the recent years production has been increased from 1477.58 million tons to 2596.63 million tons. Despite, the increased in production by 56%, huge amounts of chili still being imported to meet the demand of the increased population. During the studied period, significant growth has been recorded in productivity, it has raided from 1.8 tons/ha to 3 tons/ha. This tremendous growth in yield was attributed to use of HYV seed and adoption of advanced production process [8].

The growth in area, production and yield during the studied period have been presented in Table 3 . The findings revealed that trend coefficient value for area and production was negative whereas, positive for productivity. The production, productivity and export were statistically significant and area were not significant. Overall, the significant growth was observed in production and productivity have exhibited growth, with compound annual growth rates (CAGR) of 5.22% and 4.61%, per year, respectively [23]. The increased in productivity was attributed to red chili is rising due to the development and dissemination of HYVs as well as the widespread adoption of Guntur Sannam-S4 varieties of red chilies [8]. The rising in prices of red chilli attracts the producers which leads to increase in acreage and production. The strong correlation (0.77) also observed in between the production and export of red chilli. The significant growth was recorded in export of red chilli with CAGR of 8.04 per cent implying flying demand for the Indian red chilli in world market. The export has increased from 2009-10 to 2023-24 during the same period.

The average productivity of red chilli in India was approximately 2 tons per hectare Between 2009-10 and 2023-24, which is relatively low for a leading producer. This indicates that India's high overall production is primarily driven by the extensive area under cultivation rather than yield efficiency. In contrast, competitive countries such as China achieve an average productivity of 6.01 tons per hectare which was three times that of India [24]. This disparity is a significant concern, especially considering that land availability is becoming a limiting factor.

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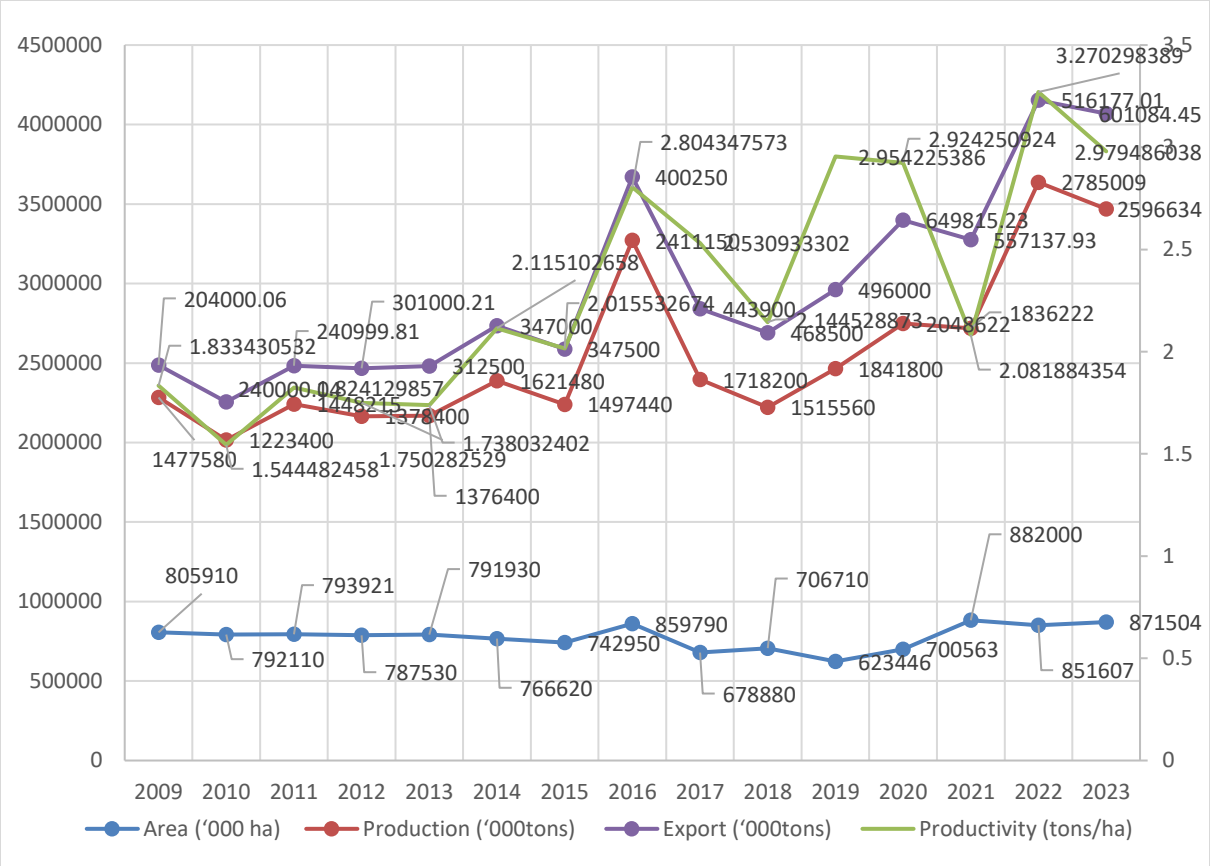

Figure 1.
Trend and growth in area, production and productivity of red chili in India (2009-2023).

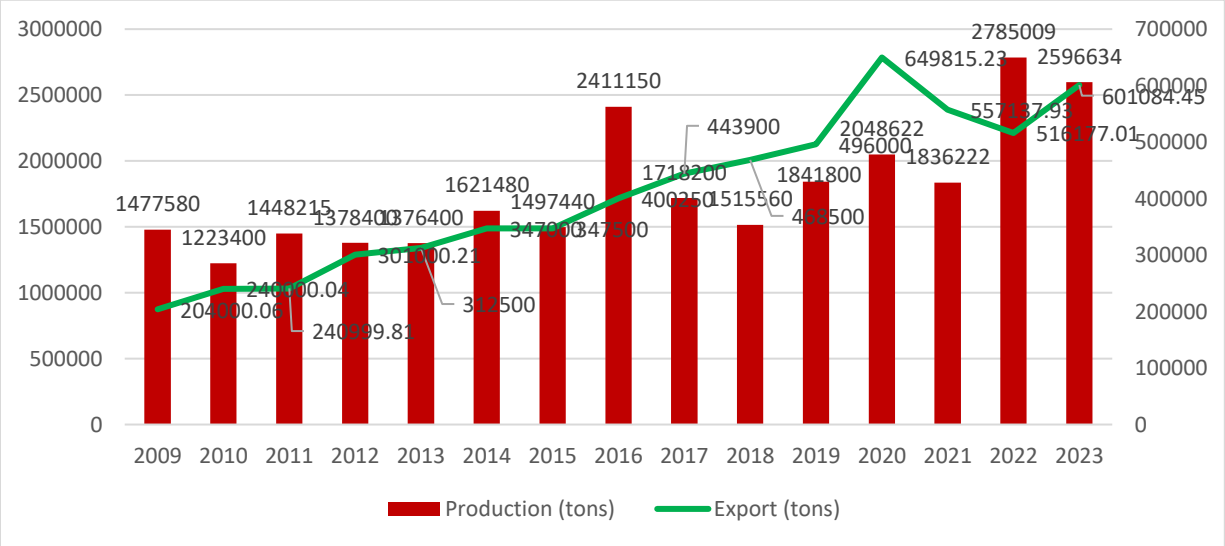

Figure 2.
Trend and rate of growth in production and export of red chili in India (2009-2023).

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Table 2.
Trend and growth in area, production and productivity of red chili in India (2009-2023).

	Area	Production	Productivity	Export
F Statistic	1.93	34.93	29.05	145.83
T Statistic	1.39	5.91	5.39	12.08
P Value	0.19	0.00	0.00	0.00
CAGR	0.66	5.22	4.61	8.04

3.2. Trend And Growth Rates in Area, Production, Productivity and Export of Small Cardamom in India

The Elettaria cardamomum commercially grown in southern India, Sri Lanka, Central America, and Southeast Asia, it has been historically referred to as the "queen of spices. In many parts of the world, it complements savory and sweet foods. Small Cardamom was used in ancient traditional medicine to treat obesity and digestive issues. It is still used in local communities today to treat conditions like bronchitis, depression, dysentery, influenza, and infections [25]. Indian ranked second in production with average production of 18464 metric tons from the area of 0.072 million ha. Kerala, Karnataka and Tamil Nadu are major hub of small Cardamom production [26]. During the period of 2009-10 to 2023-24, production have raised from 15700 MT to 25230 MT (Figure 3). This increasing in production was because of productivity growth and the output of adopting different HYVs like Malabar, Mysore, and Vazhukka [8]. The result of the semi-log model was presented in Table 3. The value of the F test reveals the significance for the area, production, productivity and export of small cardamom in India. The production and productivity have shown the positive growth with a CAGR of 3% and 4.13% per annum, but negative growth was recorded in area with a CAGR of -1.15% per annum, these results are was aligned with findings of given by Thomas, et al. [27]. From fig. 4 it was clear that, there is strong positive correlation (0.81) between production and export of small cardamom. The highest export of cardamom was 10571.25 metric tons (2021-22) during the period and it has increased with CAGR of 9.17 per cent from 1974.96 tons during 2009-10 to 6168.26 tons during 2023-24.

The area under production has been continuously declining due to several longstanding reasons, yet no effective measures have been implemented to address these issues. Key factors include the degradation of cardamom hills, rising deforestation, and crop shifting driven by rising production costs, price volatility, and challenges in marketing small cardamom [28]. Additional contributing factors are the escalating cost of cultivation, uneconomical prices, and adverse climatic conditions such as summer droughts (notably the North East Monsoon drought of 2016), monsoon floods, and strong winds. These elements have collectively had a detrimental impact on crop production during the post-WTO period [29].

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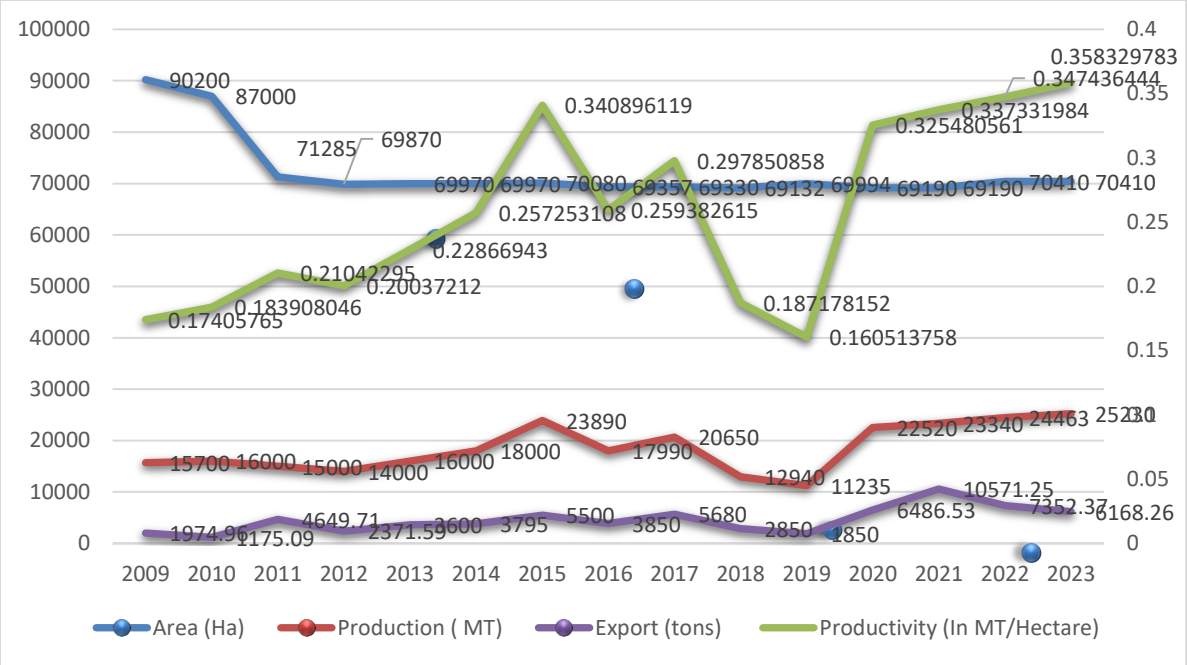

Figure 3.
Trend and growth in area, production and productivity of small cardamom in India (2009-2023).

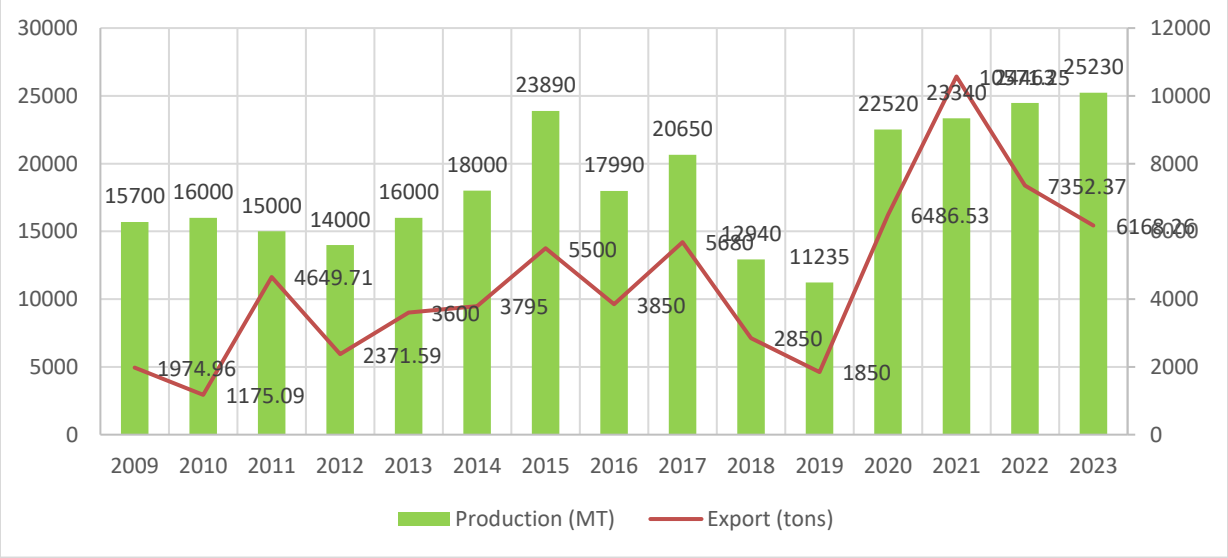

Figure 4.
Trend and rate of growth in production and export of Cardamom in (2009-2023).

Table 3.
Trend and growth in area, production and productivity of small cardamom in India (2009-2023).

	Area	Production	Productivity	Export
F Statistic	5.53	54.65	34.56	10.82
T Statistic	-2.35	7.39	5.88	3.29
P Value	0.04	0.00	0.00	0.01
CAGR	-0.65	6.35	5.90	9.17

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3.3. Trend and Growth Rates in Area, Production, Productivity and Export of Fenugreek seed in India

Fenugreek seed is commercially cultivated across several Indian states, with extensive production in Rajasthan, Gujarat, Madhya Pradesh, Uttar Pradesh, Maharashtra, and Punjab. India is the world's leading producer of fenugreek, contributing approximately 80% of the global output [30]. Fig. 5 indicated that the area of fenugreek seed production is rising over time as the area of fenugreek seed was 103542 ha during 2009-10 comparing 145366 ha during 2023-24. About 184616 metric tons of average production of fenugreek seed under average area of 136602 hectors from 2009-10 to 2023-24 and productivity of fenugreek seed production also increased from 1.2 to 1.6 metric tons per hectare during the period.

The result from the semi-log function of fenugreek seed for the area, production and productivity of Fenugreek seed in India were presented in Table 4. It was indicated from the table that F statistics were significant, which indicates that the model was significant for area, production, productivity and export of Fenugreek seed in India. The positive compound growth rate reveals that area, production and productivity of fenugreek seed increased by 4.09%, 7.33% and 3.11% per annum, respectively. Fig 7 reveals that the correlation between production and export was moderate to strong with correlation of 0.61. Lal [31] found the average yield of FLDs employing improved varieties and scientific technologies exceeded that of farmers' traditional practices by 23.51%. The noteworthy increase in fenugreek seed exports, with a compound annual growth rate (CAGR) of 3.29 percent, suggests that there is a sluggish demand for Indian fenugreek seed on the global market. To increase export value, we need to improve the quality and fulfill the standards which are recommended by the importing countries.

The average productivity of fenugreek in India was 1 ton per hectare, which is significantly lower than the global average of approximately 1.8 tons per hectare. There are certain varieties yield around 3.3 tons per hectare, nearly 3 times higher than the Indian varieties [30]. As India is one of the largest producers of fenugreek seed, there is an urgent need to adopt high-yielding varieties (HYVs) and advanced cultivation practices to boost productivity.

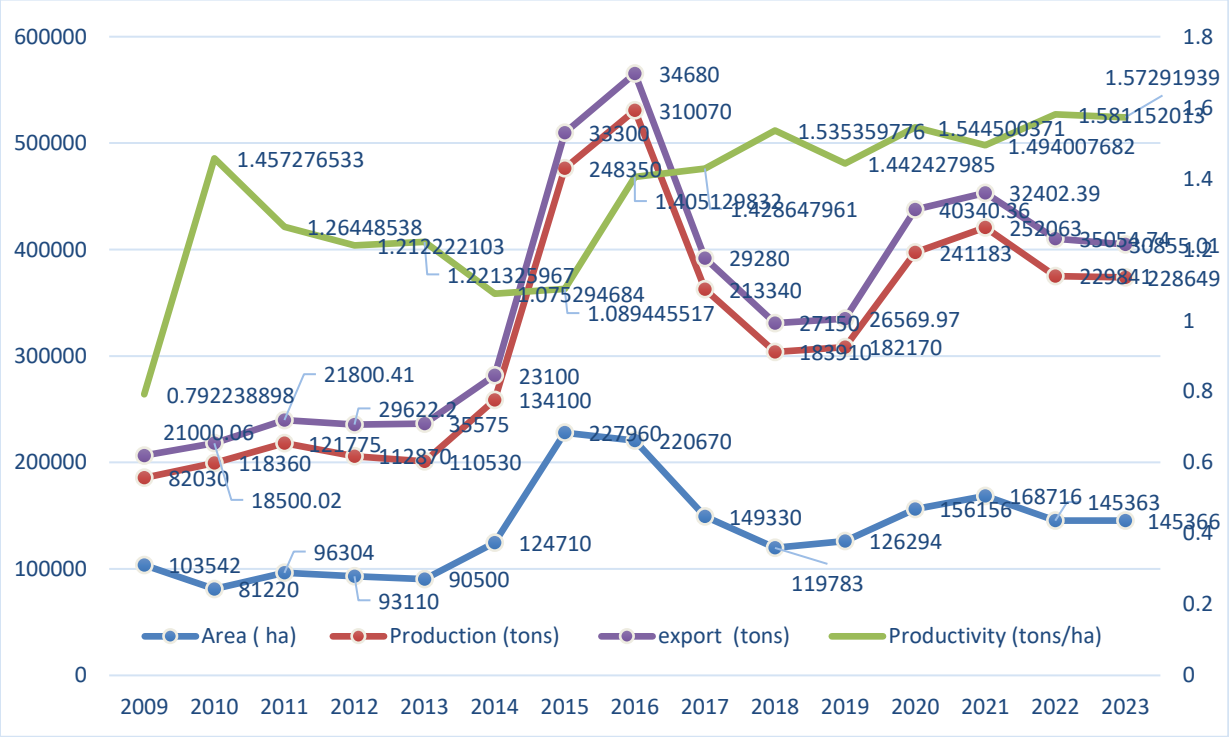

Figure 5.
Trend and growth in area, production and productivity of Fenugreek seed in India (2009-2023).

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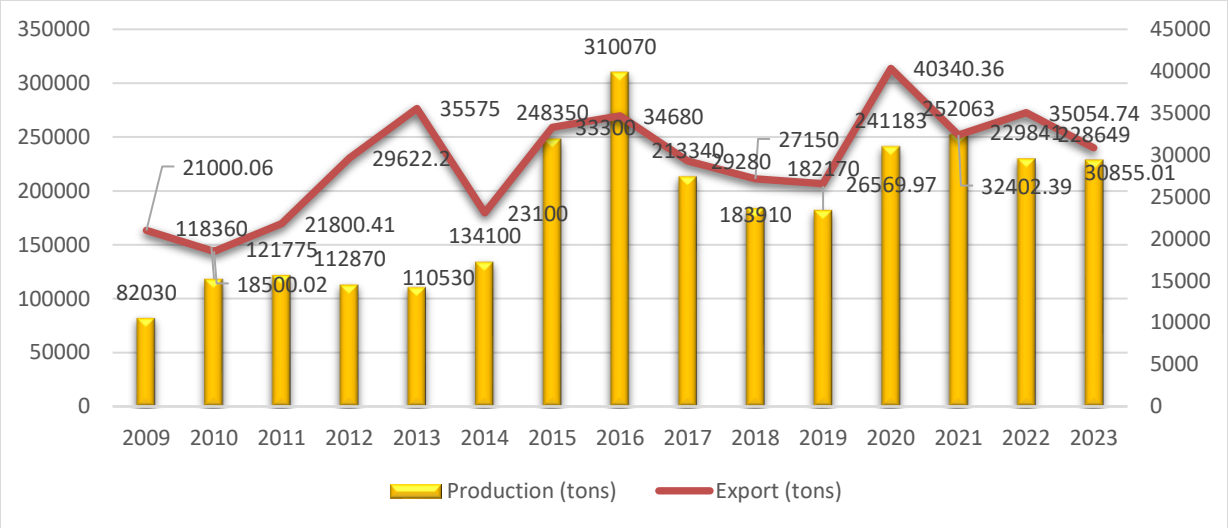

Figure 6.
Trend and rate of growth in production and export of Fenugreek seed in (2009-2023).

Table 4.
Trend and growth in area, production and productivity of Fenugreek seed in India (2009-2023).

	Area	Production	Productivity	Export
F Statistic	6.33	18.77	16.87	8.05
T Statistic	2.52	4.33	4.11	2.84
P Value	0.03	0.00	0.00	0.01
CAGR	5.32	7.45	2.08	3.29

3.4. Trend And Growth Rates in Area, Production, Productivity and Export of Celery seed in India

Celery seed (Apium graveolens L.) is a notable aromatic herb, widely grown across the globe primarily for its fresh leaves, which are highly valued as a salad ingredient. In addition to its foliage, the dried seeds of celery are prized as a valuable spice. The worldwide annual production of celery seed oil is estimated to be around 50 tonnes, with India accounting for nearly half of this total output [32]. The principal celery seed producing regions in India encompass the states of Punjab specifically the districts of Jalandhar, Gurdaspur, and Amritsar—alongside Haryana and western Uttar Pradesh, notably Ladhwa and Saharanpur districts. During the 2023-24 period, celery cultivation occupied approximately 30,820 hectares, yielding a production volume of 51,440 metric tonnes.

As illustrated in Fig. 7, the cultivation area for celery seed has expanded markedly from 8,100 hectares in 2009-10 to 30,820 hectares in 2023-24. Concurrently, production surged by an extraordinary 16%, escalating from 8,300 metric tonnes to 51,440 metric tonnes. This growth was accompanied by an enhancement in productivity, which rose from 1.03 metric tonnes per hectare to 1.67 metric tonnes per hectare. Despite these gains, the productivity rate of celery seed in India remains less than optimal. Statistical analyses reveal that production, productivity, and export figures exhibit significant positive trends, whereas the expansion of cultivation area is statistically insignificant. Nevertheless, the compound annual growth rates (CAGR) reflect encouraging upward trajectories, with area, production, and productivity increasing at rates of 2.98%, 5.56%, and 2.50% per annum, respectively. Fig. 8 further demonstrates a modest positive correlation coefficient of 0.19 between production and export volumes. Exports have grown at a CAGR of 3.54%, rising from 5,000.05 tonnes in 2009-10 to 6,598.59 tonnes in 2023-24.

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Celery seed exports are minimal compared to other spices, and its productivity is also quite low, at around 1 ton per hectare. There are many high-yielding varieties (HYVs) like A-Cel-2, EC-99249-1 and PRL-85-1 are cultivated, producing approximately 8 to 10 tons per hectare [32].

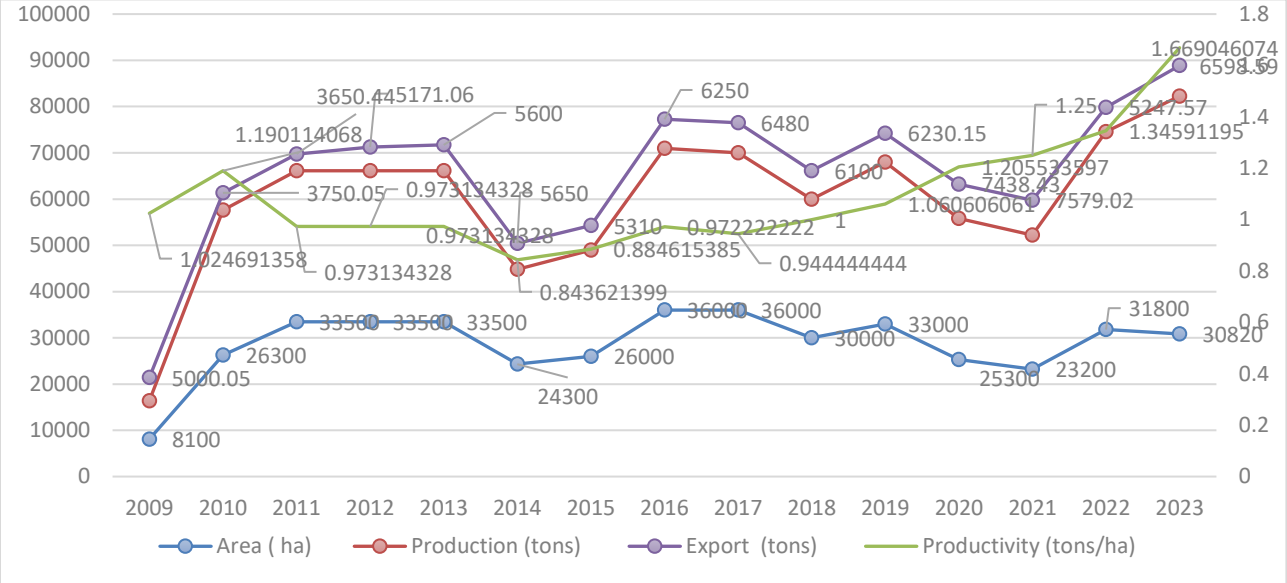

Figure 7.
Trend and growth in area, production and productivity of celery seed in India (2009-2023).

Figure 8.
Trend and rate of growth in production and export of celery seed in (2009-2023).

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Table 5.
Trend and growth in area, production and productivity of celery in India (2009-2023).

	Area	Production	Productivity	Export
F Statistic	1.16	8.69	8.39	16.50
T Statistic	1.08	2.95	2.90	4.06
P Value	0.30	0.01	0.01	0.00
CAGR	2.98	5.56	2.50	3.54

3.5. Instability in Area, Production, Productivity and Export of Some Major Spices in India

Figure 9 illustrates the volatility in area, production, productivity, and export among four principal spices cultivated in India. A comprehensive instability assessment reveals that celery seed production exhibited moderate instability at 24.78%, closely followed by fenugreek seed at 24.39%. In contrast, small cardamom and red chilli demonstrated comparatively lower instability in production, registering 11.24% and 14.40% respectively, over the period from 2009-10 to 2023-24.

Examining the area under cultivation, celery displayed moderate instability at 24.60%, with fenugreek seed slightly higher at 29.66%. Cardamom (7.99%) and chilli (9.38%) were notably more stable in this regard when compared to their counterparts. In terms of productivity, celery seed again presented moderate instability, whereas small cardamom (14.97%), fenugreek seed (11.59%), and red chilli (13.98%) maintained relatively stable productivity levels. The dependence of red chilli on specific agro-climatic zones restricts its cultivation to limited areas, thereby reducing the scope for significant variability in the total area under production. This geographical limitation stabilizes the red chilli growing area but also poses challenges for expanding production beyond these zones [33]. The area under fenugreek seed cultivation is not fixed but varies in response to the relative profitability of other crops grown in the same region. This economic decision-making by farmers is the primary driver behind the instability in fenugreek seed production area [34].

With respect to export trends, small cardamom experienced pronounced instability at 42.38%, while fenugreek seed exports were moderately unstable at 17.36%. Conversely, celery seed and red chilli exports exhibited low instability, with indices of 13.55% and 10.06% respectively. The export value of Indian small cardamom is highly sensitive to price fluctuations because export earnings are directly linked to export unit prices therefore, it played a major role in destabilizing the value of small cardamom export from India [35]. Studies show that about 97% of the variation in the yearly market price of small cardamom can be explained by changes in export volume and export price, highlighting the dominant influence of price on export value [36].

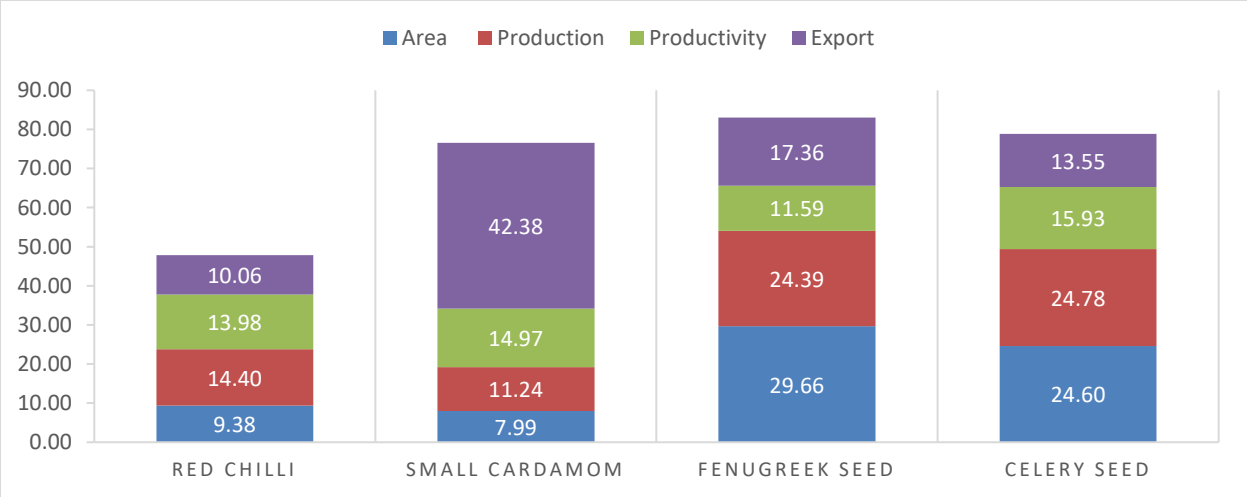

Figure 9.
Instability in area, production, productivity and export of some major spices in India (2009-2023).

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4. Conclusion and Policy Implications

The analysis reveals that the area, production, productivity, and export of major spices in India have shown significant growth. However, this growth rate remains insufficient to fully meet the rising domestic demand. Notably, production of key spices such as red chilli, small cardamom, fenugreek seed, and celery seed has experienced positive growth. While productivity across all spices has improved in recent years, India's spice yields still lag considerably behind those of other countries, raising serious concerns about future global competitiveness. To enhance profitability and strengthen India's position in the international market, it is imperative to focus on boosting productivity through the adoption of HYVs and advanced cultivation practices. Since export volumes are directly linked to production capacity, increasing yields will naturally support higher export potential. A positive correlation between production and export across all major spices indicates that as production rises, export levels tend to increase correspondingly. Despite these gains, most spices exhibit moderate instability in terms of area, production, productivity, and export over time. Various factors contribute to this volatility, and identifying these sources is crucial for the sustainable development of India's spice sector. Among these, price volatility stands out as a major driver of export instability. Addressing this challenge requires improvements in storage facilities, grading standards, market information dissemination, and cultivation techniques to stabilize and enhance export performance.

To achieve these goals, robust research and policy support are essential. Significant investment in research and development focused on spices will be critical to raising productivity, reducing instability, and ensuring long-term growth. By prioritizing innovation and strategic interventions, India can secure its leadership in the global spice market while meeting domestic demand more effectively.

5. Strategies for Boosting Spice Trade

To enhance spice production and exports, it is essential to increase yields by adopting advanced technologies alongside high-yielding varieties. Improving product quality and providing robust testing facilities are critical for compliance with sanitary and phytosanitary (SPS) and technical barriers to trade (TBT) standards. Promoting advanced technology and good agricultural practices (GAP) will boost production capacity to meet growing demand. Establishing a dynamic information-sharing mechanism between state and central authorities, along with ensuring testing facilities for SPS and TBT compliance, is vital. The Spice Board plays a key role in expanding export markets, and policies like One District One Product (ODOP) can help achieve export targets. Additionally, creating an integrated web portal for real-time updates on tariffs, non-tariff measures, and pesticide residue limits will support an efficient global market intelligence network.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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