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Dynamics of production and export potential of cauliflower in India: A growth and stability analysis

¹Shouvik Kar, ¹Gobinda Mula, ¹Ashutosh Sarkar and ²Manoj Kanti Debnath

¹Department of Agricultural Economics, Uttar Banga Krishi Viswavidyalaya, Cooch Behar, West Bengal, India

²Department of Agricultural Statistics, Uttar Banga Krishi Viswavidyalaya, Cooch Behar, West Bengal, India

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Corresponding Author: Gobinda Mula

Abstract

Cauliflower is an important Cole crop as well as commercial crop contributed 4.71% of mean production share to the total vegetables in India. Present study explored the trends of area, production, productivity and export potential of cauliflower in India using secondary data. Statistical tools such as mean, standard deviation, Compound Annual Growth Rate (CAGR) and Cuddy–Della Valle Instability Index (CDVI) were employed for the analysis. India continuously occupied as a 2nd largest global cauliflower producer with a mean production of 8733.09 million kg over last ten years with average annual growth rate of 1.93% and least instability of production (CDVI 2.63). The average domestic growth rate (CAGR) of area and production found to be 3.01% and 3.29% respectively over last 25 years. Whereas positive trend in productivity revealed much lower (0.27%) than area and production. West Bengal followed by Madhya Pradesh and Bihar altogether contributed around 47% of the total national average production of last 10 years. The study also found that the primary markets of cauliflower from India are Nepal, Bhutan and Maldives. However, India could not hold any position among the top 10 global exporters of cauliflower instead of being 2nd largest global producer might be due to high domestic consumption as well as low level of productivity. Hence, development of high yielding climate resilient varieties, scientific crop management, cold-chain and value addition infrastructure facilities, as well as backward and forward market linkage to boost overall production and export capabilities of cauliflower in India.

Keywords: Cauliflower, CAGR, export potential, instability, trend

1. Introduction

India ranks as the 2nd largest producer of horticultural crops in the world ^[1]. The horticulture sector contributed 38% to the Gross Value Added (GVA) of agriculture, playing a significant role in the Indian economy ^[2]. Vegetable sector alone contributed for 58.41% of total horticulture GVA and contributes Rs. 7,378.14 crore to India's national export earnings ^[2,3]. India stood as the world's largest producer, exporter and consumer of vegetables, earning it the title of the 'Basket of Vegetables' and India's diverse climatic conditions are highly suitable for cultivating a wide variety of vegetables ^[1]. The major vegetables cultivated in India include potato, onion, tomato, brinjal (eggplant), cabbage, cauliflower, okra, peas, radish and bottle gourd ^[4,5].

Cauliflower (*Brassica oleracea* var. *botrytis* L.) is widely regarded as the "King of Cole crops" belongs to Brassicaceae family ^[6]. The immature curd of cauliflower is the edible part, highly rich in vitamins, minerals and dietary fiber ^[7]. Cauliflower is recognized for its therapeutic value, contributing to the prevention of chronic ailments, including cancer and cardiovascular diseases ^[8,9]. Cauliflower is consumed both raw and cooked form and also used as a key ingredient in dishes such as curries, noodles, burgers and sandwiches ^[10,11].

At the global level, cauliflower is grown on 1.23 million

hectares, producing nearly 68.22 million tons, with a productivity of 18.1 tons per hectare ^[12]. India is the 2nd largest producer of cauliflower after China, producing 15.06% of total global production during 2024-25 with a mean production of 8733.09 million kg ^[13,14]. The other principal global producers are United States, Mexico, Spain, Türkiye, Italy, Pakistan, Bangladesh and Algeria ^[15]. In India, the major cauliflower producing states are West Bengal, Bihar, Madhya Pradesh, Odisha, Gujarat where the first three states altogether contributed 46.42% of national production ^[2].

Cauliflower is an important vegetable with regard to its economic and nutritional value, but its cultivation in India is facing many problems like fluctuating productivity, climate variability, occurrence of pests and diseases, increase in cost of inputs and post-harvest losses and these problems often result in unstable income for most of the cauliflower growers who are small and marginal farmers ^[16]. Despite the considerable progress achieved in terms of area expansion and production, there is an urgent need to enhance productivity, improve efficiency in the use of resources and strengthen market linkages. In this context, the present study attempts to analyse the trends in area, production and productivity of cauliflower in India with special reference to growth and instability.

2. Materials and Methods

The study was conducted using secondary data sources. The information on area, production, productivity and exports was collected from various government institutions viz. Agricultural and Processed Food Products Export Development Authority, Department of Economics and Statistics as well as from key websites such as Indiatat, Tridge and Agriwelfare to fulfill the specific objectives of the study. The study analyzed the trends, growth patterns and stability of cauliflower production and exports in India.

2.1 Analytical Techniques: Basic descriptive statistical tools such as mean, standard deviation, Cuddy–Della Valle index (CDVI) and percentages were used for data analysis. The mean helped in estimating the average levels of area, production, productivity and export of cauliflower. while the standard deviation (SD) was used to assess the extent of variation or dispersion of the data around the mean.

2.1.1 Compound Annual Growth Rate (CAGR): To examine the trend in cauliflower production and productivity, the Compound Annual Growth Rate (CAGR) was applied. The CAGR for area, production, and productivity of cauliflower was estimated using an exponential growth function of the following form:

$$Y = ab^t e^u$$

Where, Y is dependent variable (area/production/productivity), a = intercept term, b = (1+r) and 'r' is the compound growth rate, t = time trend, u = Random error term

The above model in the Logarithmic form is expressed as: $\ln Y = \ln a + t \ln b + u$

$\ln a$ and $\ln b$ values were obtained using the methods of ordinary least squares and per cent CAGR was computed using the following relationship: % CAGR = (Antilog of $(\ln b) - 1$) $\times 100$.

2.1.2 Cuddy–Della Valle index: The Cuddy–Della Valle Index (CDVI) was employed to overcome the drawbacks of the coefficient of variation [17]. This index was used to measure the instability of the prices, areas, production and productivity. CDVI was computed using the following formula:

$$\text{Cuddy–Della Valle Index (CDVI)} = CV \times \sqrt{1 - R^2}$$

where CV is the coefficient of variation (%) and R^2 is the time-trend regression coefficient of determination.

2.1.3 Significance Test of Growth Rate: To determine whether the estimated growth rates were statistically significant, the Student's *t*-test was employed. The significance of the regression coefficient was evaluated using the following formula:

$$t = \frac{b}{SE(b)}$$

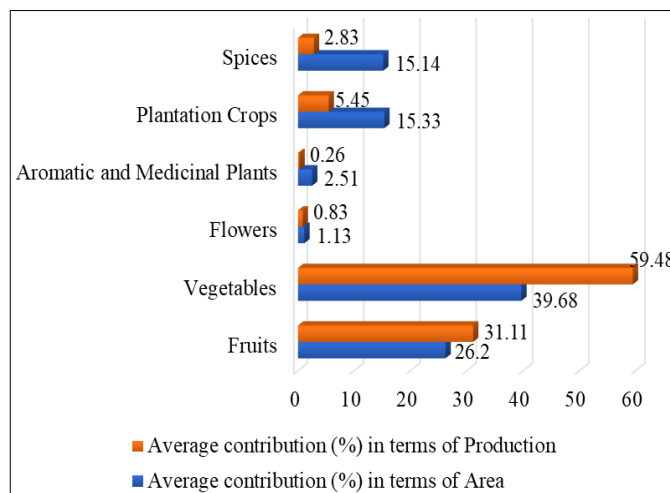
Where, b = Estimated regression coefficient, $SE(b)$ = Standard error of the coefficient

The calculated *t*-value was compared with the tabulated *t*-value at the 1% or 5% level of significance.

3. Results and Discussion

3.1 Growth and Export Dynamics of Cauliflower Production:

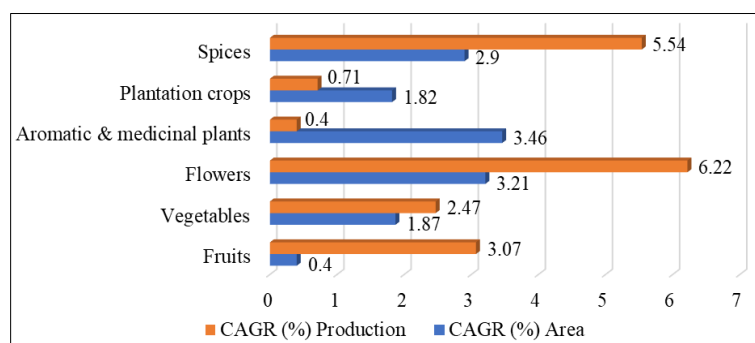
The relative average share of different sectors of horticulture viz. spices, plantation crops, aromatic and medicinal plants, flowers, vegetables and fruits was worked out based on secondary data on area and production (from 2011-12 to 2024-25) and presented in Fig. 1. The results showed that the vegetables had the highest share of the total horticultural cropped area during the specified period to the tune of 39.68% followed by fruits (26.20%), plantation crops (15.33%) and spices (15.14%). The same trend was revealed in production, vegetables accounting the highest share of horticultural production (59.48%), followed by plantation crops (5.45%), fruits (31.11%) and spices (2.83%). The above findings indicated that area and production of horticultural crops of India persistently dominated by vegetable sector.



Source: www.indiatat.com

Fig 1: Average share of different sectors of Horticulture in area and production in India (FY 2011-12 to FY 2024-25)

Trend in growth (CAGR) of different sectors of Horticulture in area ('000 ha.) and production ('000 MT) over last thirteen years (from 2011-12 to 2024-25) was estimated and depicted in Fig 2. Although the vegetable sector holds first rank in terms of production, but the annual growth rate (CAGR) of production of vegetables (2.47%) over the same period observed to be lower than all other horticultural sector viz. flowers (6.22%), spices (5.54%), aromatic and medicinal plants (3.46%) and fruits (3.07%) except plantation crops (1.82%). However, in respect to the growth of area under cultivation vegetable sector occupied 3rd position preceded by flowers and spices. The findings indicated a moderately progressive and healthy development of the vegetable sector over the years.

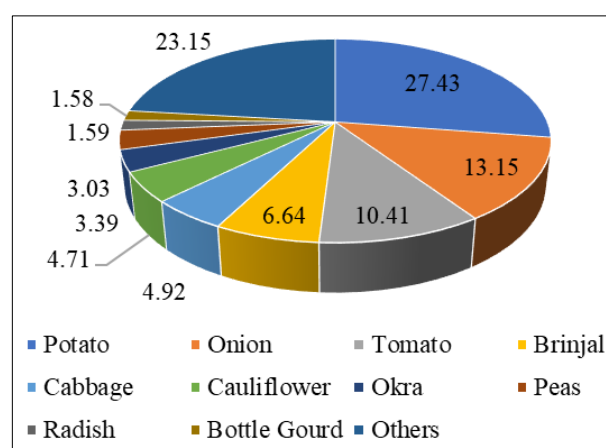


*CAGR, Compound annual growth rate (Source: www.indiastat.com)

Fig 2: Trend in growth (CAGR) of different sectors of Horticulture in area ('000 ha.) and production ('000 MT) over last thirteen years (from 2011-12 to 2024-25)

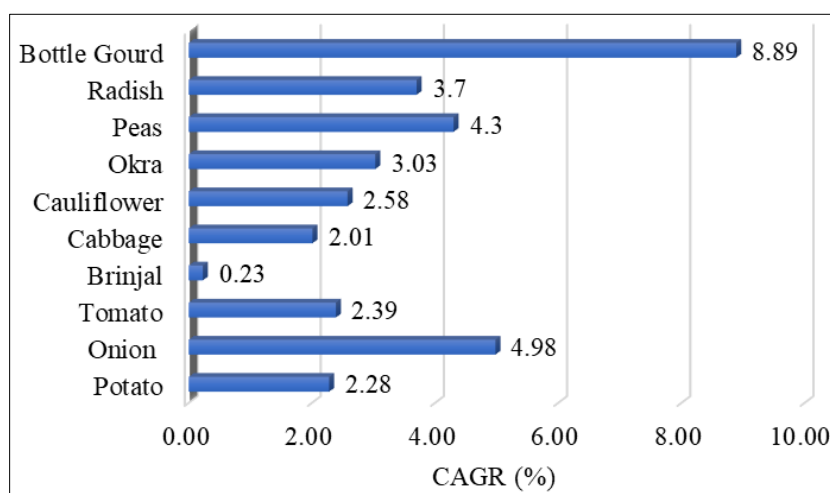
The mean production share of major vegetables produced in India was computed with the last ten years production data (2014-15 to 2024-25) and demonstrated in Fig. 3. It was observed that major contribution to the total mean production of vegetables came from potato, onion and tomato, altogether constituted 51% of total vegetable production in India. Whereas cauliflower only contributed 4.71% of total vegetable production. On the other hand, the growth trend of production of major vegetables over the same period was worked out in terms of compound annual growth rate (CAGR) and shown in Fig 4. It showed production of all the major vegetables raised with positive trend. The average annual growth (CAGR) observed to be highest in bottle gourd (8.89%) and lowest in brinjal (0.23%). Whereas, Cauliflower ranked 6th position in terms of growth of production with annual growth rate (CAGR) of 2.50%. It was also noticed that cauliflower had a steady growth rate higher than cabbage (2.01%), tomato (2.39%) and brinjal (0.23%). Improved varieties and modern technologies of vegetable cultivation with commercial approach might be the reasons for positive trend in vegetable production. The results inferred that cauliflower production could be enhanced over the years to

augment the export potential keeping domestic demand intact.



Source: www.indiastat.com, Horticultural Statistics at a Glance 2021 and Agricultural statistics at a glance 2024

Fig 3: Mean production share (%) of major vegetables (2014-15 to 2024-25)



*CAGR, Compound annual growth rate (Source: www.indiastat.com, Horticultural Statistics at a Glance 2021 and Agricultural statistics at a glance 2024)

Fig 4: Trend in production of major vegetables in India over last ten years (2014-15 to 2024-25) in India

3.2 Global Position of Cauliflower Production and Trend:

The production data of top ten cauliflower producing countries was used to compute the mean production, trend in

production (CAGR) and variability of production (CDVI), presented through table 1. The analysis revealed that India was found to be the 2nd largest producer of cauliflower after

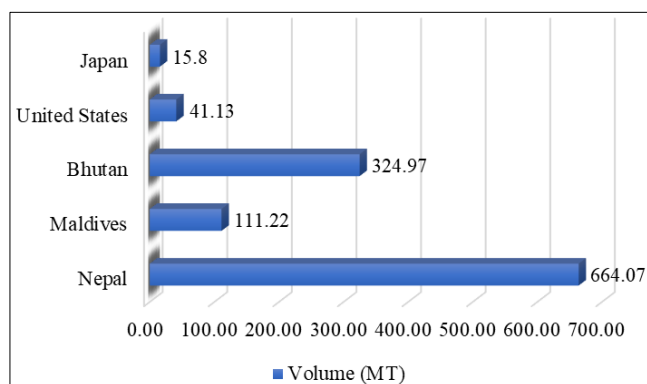
China with mean production of 8,733.09 million Kg. and had a positive trend in growth (CAGR of 1.93) significant at 1% level of probability. However, annual growth rate of production of India found to be higher than China (0.65%) but lower than Algeria (8.08%), Bangladesh (7.55%), Türkiye (6.62%), Mexico (4.79%) and Pakistan (4.24%). The instability analysis (CDVI) indicated that the variation in production over the same period for India was 2.63% only, slightly higher than China. The instability index of India inferred the relatively stable production with positive growth trend over the years implying a favorable position of India in the world production of cauliflower.

Table 1: Major country wise production of cauliflower (Million Kg.) of last 10 years (From 2014-15 to 2024-25)

Rank	Country	Mean Production	CDVI	CAGR
I	China	9582.36	1.59	0.65**
II	India	8733.09	2.63	1.93***
III	United States	1216.09	5.48	-1.84*
IV	Mexico	646.14	6.71	4.79***
V	Spain	664.08	7.43	1.65*
VI	Türkiye	283.23	2.70	6.62***
VII	Italy	372.83	1.93	-0.72***
VIII	Pakistan	241.06	16.07	4.24*
IX	Bangladesh	271.45	8.73	7.55***
X	Algeria	202.55	6.53	8.08***

CAGR, Compound annual growth rate; CDVI, Cuddy–Della Valle instability index. (Source: www.indiastat.com)

The major export destinations of cauliflower based on export volume depicted in Fig. 5. Among the importing countries, Nepal was the largest importer of cauliflower followed by Bhutan and Maldives. However, the volume of exports to the developed countries, like the United States and Japan, was limited might be due to the low demand as well as low standard of quality. It can be observed that the export market for cauliflower was mainly concentrated around neighboring countries around South Asian region might be due to the geographical proximity, cost of transportation and trade relations.

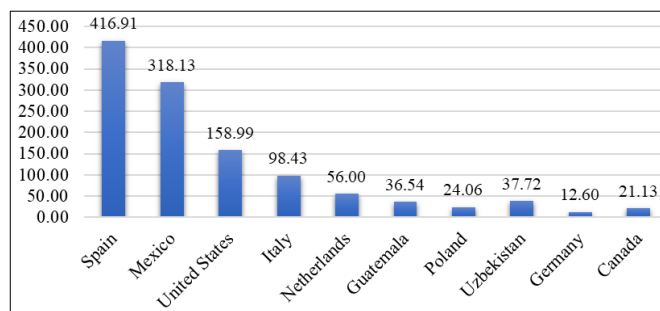


Source: www.tridge.com

Fig 5: Major exports destination of cauliflower from India during 2024-25

The key global exporters of cauliflower in terms of export quantity were presented in Figure 6 which shows that, Spain and Mexico were the lead global exporters of cauliflower. Out of top ten, the other global player of cauliflower export

were the United States, Italy, Netherlands, Guatemala, Poland, Uzbekistan, Germany and Canada. It is quite evident from the Fig. 6. that India could not hold any position among the top ten global cauliflower exporters instead of being the 2nd highest global producer of cauliflower might be due to the highest domestic consumption.



Source: www.tridge.com

Fig 6: Major global exporters of cauliflower in terms of volume ('000 MT) during 2024-25

The finding suggested that Spain, Mexico, United States played a significant role in world trade of cauliflower might be due to the developed and sophisticated supply chain infrastructures and export-oriented production practices. of the major producers in the world, it was not one of the leading exporters, suggesting there is a significant portion that is consumed within the country. To achieve a good position in the global trade of cauliflower, India has to introduce export-oriented production practices with modern technology, improved post-harvest management and processing facilities as well as development of export logistics. Further, India has to search more export destinations of cauliflower particularly the European countries, Canada, Malaysia and USA to increase the export competitiveness in the international markets.

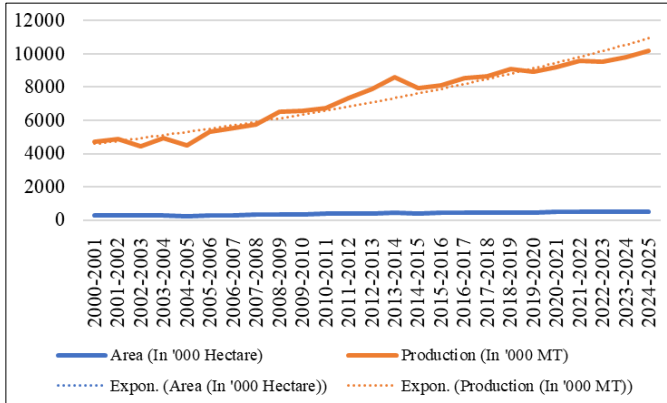
3.3 Area, Production and Productivity of Cauliflower in India: Trends and Patterns:

To investigate the growth and trend of cauliflower cultivation in India twenty-four years (2000-01 to 2024-25) data related to area, production and productivity was analyzed and presented in Table 2. The mean production of cauliflower cultivation was estimated at 7,335.38 '000 MT with a mean productivity of 18.92 MT ha⁻¹. The growth rate (CAGR) of area and production over the same period found to be identical to the tune of around 3% per annum. The positive trend of area and production of cauliflower in India is supported by the Fig. 7. However, the annual growth rate (CAGR) of productivity was worked out at 0.27% with a minimum fluctuation of less than 2% (CDVI: 1.87). The stagnant level of productivity might be due to the practices of traditional method of cultivation, lack of adoption of improved package of practices as well as varieties. It was also noticed that variation in area and production also identical which was less than 5% for both evident from estimated CDVI value, implying the more stability in growth of area and production of cauliflower. In a nutshell the findings showed that area and production of cauliflower was increased steadily in India with least improvement in productivity.

Table 2: Area, production and productivity of cauliflower in India from 2000-01 to 2024-25

Parameters	Area (In '000 Hectare)	Production (In '000 MT)	Productivity (In MT ha ⁻¹)
Mean	385.36	7335.38	18.92
SD	90.42	1889.47	0.59
CDVI	4.45	4.88	1.87
CAGR	3.01	3.29	0.27

SD, Standard deviation; CAGR, Compound annual growth rate; CDVI, Cuddy–Della Valle instability index. (Source: www.indiastat.com)



Source: www.indiastat.com

Fig 7: Trend in Area and Production of Cauliflower in India from 2000-01 to 2024-25

3.4 State-Wise Contribution in Area and Production of Cauliflower and Their Trend:

To examine the performance of major cauliflower growing states in terms of growth, trend, share and variability of area and production, the last ten years (from 2014-15 to 2024-25) related data was analyzed and delineated in table 3. It was observed that most significant contribution to the production of cauliflower in India came from West Bengal (22.43%), Bihar (11.74%) and Madhya Pradesh (13.11%), altogether contributed 47.28% of the total national production. However, the annual growth rate (CAGR) of production over the years observed to be highest for Punjab (9.15%) followed by Madhya Pradesh (7.85%) and Gujarat (4.28%). Whereas, the annual growth rate of production as well as area of all other states found to be less than 1.5% and even negative in some states. The findings indicated that in terms of annual growth of area and production the three states viz. Punjab, Madhya Pradesh and Gujarat were the pioneer. Contrastingly, although West Bengal was the leading contributor to the area and production of cauliflower, the growth rate in both area and production was found to be less than one, implying the stagnancy in growth. In respect to instability analysis, the CDVI value of production observed to be highest in Haryana (21.22) followed by Gujarat (10.53) and Jharkhand (8.41), but lowest in West Bengal (1.34). In case of area the same pattern was noticed. Further, the fluctuation in area and production was lower in first three leading cauliflower states indicated the more stability of area and production.

Table 3: Contribution of major cauliflower producing state in terms of area ('000 ha.) and production ('000 MT) of last ten years (From 2014-15 to 2024-25)

State	Mean			CDVI		CAGR	
	Area	Production	Productivity	Area	Production	Area	Production
West Bengal	76.95 (16.74%)	1959.06 (22.43%)	25.46	1.46	1.34	0.76	0.61
Bihar	67.09 (14.59%)	1025.20 (11.74%)	15.28	2.19	5.39	0.61	1.18
Madhya Pradesh	50.22 (10.92%)	1145.29 (13.11%)	22.81	7.19	2.90	10.01	7.85
Odisha	41.89 (9.13%)	645.12 (7.39%)	15.40	5.22	5.16	0.56	1.04
Gujarat	28.51 (6.20%)	648.64 (7.42%)	22.75	9.77	10.53	3.23	4.28
Haryana	33.74 (7.34%)	611.73 (7.00%)	18.13	13.82	21.22	-0.63	-0.12
Assam	23.82 (5.18%)	441.43 (4.96%)	18.53	4.10	5.34	2.17	1.05
Chhattisgarh	23.86 (5.19%)	468.34 (5.05%)	19.63	2.76	3.96	0.62	0.96
Jharkhand	22.21 (4.83%)	305.75 (3.50%)	13.77	10.17	8.41	-0.17	-2.27
Punjab	20.86 (4.53%)	395.48 (4.53%)	18.96	4.06	2.77	7.26	9.15
India	459.64 (100%)	8733.09 (100%)	19.00	1.47	2.63	2.12	1.93

CAGR, Compound annual growth rate; CDVI, Cuddy–Della Valle instability index (Source: www.indiastat.com)

Conclusion

Vegetable sector is the key driver of the Indian horticulture, contributing around 60% of national horticultural output with positive growth trend. Although, India is the 2nd largest global producer of cauliflower after China, cauliflower contributed only around 5% of total domestic vegetable production over the last ten years (2014-15 to 2024-25) with a stable growth rate of 1.93%. The major destination of cauliflower export from India revealed only Nepal and Bhutan. However, India could not hold any position among top ten global exporter of cauliflower instead of being 2nd largest global producer, might be due to high domestic consumption, suggested the considerable opportunity for growth in international markets. An identical positive trend in area and production was found with an annual growth rate of around 3%. Whereas, productivity growth rate was only 0.27%. The variation in

growth of productivity was lower than area and production over the years. It may be concluded that to increase the export potential productivity has to be enhanced with adoption of modern technologies and improved varieties. In India, West Bengal, Bihar, Madhya Pradesh, Odisha and Gujarat are the leading producer of cauliflower altogether contributed around 61% of total domestic production. In terms of productivity West Bengal, Madhya Pradesh and Gujarat were the pioneer. However, in terms of annual growth rate (CAGR) Punjab, Madhya Pradesh and Gujarat took the leading position. Whereas, instability of production revealed highest in Haryana followed by Gujarat and Jharkhand. Though the national production instability is very low, cauliflower cultivation is facing the challenges like climate variability, incidence of pests and diseases, high post-harvest losses etc., limiting the productivity and income of small and

marginal farmers. To enhance the domestic availability and global competitiveness of cauliflower production and export, India needs to introduce horizontal as well as vertical expansion of cauliflower cultivation along with the adoption of export-oriented production strategies by integrating modern technologies, strengthening post-harvest management and creation of agricultural export zone with adequate logistics. Further, suggested to introduce schemes for climate-resilient high-yielding varieties, Integrated Pest Management (IPM), capacity building to adopt modern technology, cold storage and processing facilities under NHB and PM Kisan SAMPADA Yojana. Moreover, motivation and financial support to producer as well as exporter might lead to enhance the export potential of cauliflower from India. Additionally, the country should explore more international destinations, particularly in major cauliflower importing countries.

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