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Performance of the Major Pulses Crop in India: Growth and Instability

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present paper deals with the comparative assessment of instability and growth rate in area, production, and yield of major pulses in India. In the analysis, Cuddy-Della Valle (CDV) instability indices and compound growth rates (CGRs) are computed on utilizing secondary time series data on area, production, and yield of major pulses (viz., chickpea, pigeon pea, urdbean and mungbean) pertaining to the period 2000-2021. The comparative assessment has been made by further classifying the concerned period into three periods i.e. period-I (2000 to 2010), period-II (2011 to 2021), and the overall period (2000 to 2021). Moreover, the statistical coefficients viz., coefficient of variation (CV) and coefficient of determination (R^2) have been measured. The findings of the investigation reveal that, during the overall period, highest instability in area is observed in urdbean, whereas the least instability in area is observed in chickpea. Among the pulses, mungbean reported highest instability in production as well as yield, whereas chickpea witnessed least instability in production as well as yield. During the overall period, the highest growth rates in area, production, and yield have been observed in chickpea.

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Keywords: Coefficient of variation; coefficient of determination; instability index; compound growth rate.

1. INTRODUCTION

Pulses are the major constituent of the human diet. Pulses contain 20 to 25 percent protein by weight, which is much higher than staples like wheat and rice. This high protein content supports health and nutrition, emphasizing their importance in daily meals and the agricultural sector.

In India, pulses are a crucial part of the diet and a major economic asset. India, being the largest producer of pulses in the world, uses this crop to boost its export revenues, highlighting its economic importance. Specifically, pulses have twice the amount of protein as wheat and three times as much as rice, making them a vital part of the Indian diet. Major pulses grown in India include chickpea (gram), pigeon pea (tur or arhar), mungbean, urdbean (black gram), masur (lentil), and various kinds of beans. The major pulse growing states are Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh, Karnataka, West Bengal, Tamil Nadu, and Kerala.

Globally, pulses are grown on about 94.14 million hectares, producing 89.74 million tons with a yield of 953 kg per hectare. India, with over 35 million hectares dedicated to pulses, is the largest producer in the world. It leads globally, contributing 37% of the total area and 29% of the total production. In the 2021-22 period, India's productivity reached 932 kg per hectare, showing a significant increase over the past five years (Source: Directorate of Pulses Development, Govt. of India [1]).

Chickpea (*Cicer arietinum* L.) are annual legumes belonging to the Fabaceae family, and the third most significant legume crop globally. Within the pulses category, chickpeas are a crucial crop in semi-arid tropics and warm temperate regions, with India being the leading producer. Chickpeas are highly nutritious, providing over 20% of the daily value (DV) for protein, dietary fiber, folate, and essential minerals such as iron and phosphorus. Thiamin, vitamin B6, magnesium, and zinc are present in moderate amounts, offering 10–16% of the DV. In the 2021-22 crop year, India produced 13.75 million tonnes of chickpeas from 10.91 million hectares, achieving a productivity of 12.6 quintals per hectare [2,3]. Chickpeas account for nearly 50% of India's pulse production, with major producing states including Maharashtra (25.97% of national production), Rajasthan (20.65%), Madhya Pradesh (18.59%), Gujarat (10.10%), and Uttar Pradesh (5.64%) (Source: ICAR-Indian Institute of Pulse Research [4]).

Pigeon pea (*Cajanus cajan* L.), commonly known as Arhar, is a short-lived perennial commonly cultivated as an annual legume from the Fabaceae family. The seeds of pigeon pea are rich in iron, iodine, and essential amino acids such as lysine, threonine, cysteine, and arginine. They are an excellent source of vegetarian protein, with 100 grams of dry seeds providing 343 calories and 21.70 grams of protein, or 39% of the recommended daily value. A 100-gram serving contains 117% of the daily value for copper, 65% for iron, 78% of manganese, 52% for phosphorus, 15% for selenium, 13% for calcium, and 25% for zinc.In the 2022 crop year, India produced 4.34 million tonnes of pigeon pea in 5.05 million hectares, achieving a productivity rate of 860 kg per hectare (Source: Directorate of Economics & Statistics, Govt. of India [5]).

Urdbean (*Vigna mungo* L.), commonly known as Black Gram, is an annual legume from the Fabaceae family, mainly grown in the warmer regions of South and Southeast Asia. It is a staple in Indian cuisine and serves as a crucial pulse crop during both the *kharif* and *rabi* seasons in India. The nutritional profile of black gram varies between its raw and cooked forms. Raw black gram contains high levels of protein (25 g/100 g), potassium (983 mg/100 g), calcium (138 mg/100 g), iron (7.57 mg/100 g), niacin (1.447 mg/100 g), thiamine (0.273 mg/100 g), and riboflavin (0.254 mg/100 g). In the 2022 crop year, India produced 2.78 million tonnes of urdbean from 4.64 million hectares, achieving a productivity of 600 kg per hectare (Source: Directorate of Economics & Statistics, Govt. of India [5]).

Mungbean (*Vigna radiata* L.),commonly known as Green gram, is an annual legume from the Fabaceae family and is a cost-effective and essential pulse crop widely grown in the subtropical regions of South and Southeast Asia. Like other pulses, mung beans are nutritionally balanced, offering a variety of vitamins, minerals, and beneficial enzymes, making them a great addition to a healthy diet. Mungbeans are highly valued for their nutritional content, with about 55–65% carbohydrates (approximately 630 g/kg dry

weight) and a significant protein content of 20–50% by dry weight, primarily consisting of globulins (60%) and albumins (25%). Mungbean contributes 10% of total pulse production and occupies 16% of the area dedicated to pulses.In the 2022 crop year, India produced 2 million tonnes of mungbean from 4.70 million hectares, achieving a productivity of 430 kg per hectare (Source:Directorate of Economics & Statistics, Govt. of India [5]).

Since pulses are vital source of protein and consumed worldwide as human diet, hence, in recent years, several researchers have conducted studies on pulses. Getachew and Abraham [6] evaluated the performance of chickpea varieties based on growth and yield parameters by conducting a field experiment using split plot design. Sefera et al. [7] investigated the effect of plant population and NPS fertilizer rates on yield and yield components of mungbean using Randomised Complete Block Design with three replications. Vogelsang-O'Dwyer et al. [8] provided a detailed overview of pulse proteins and the dry and wet fractionation methods used to produce high-protein ingredients. Also, the application of pulse protein ingredients in milk alternatives was explored. Gurusamy et al. [9] elaborated the aspects of pulse grains for healthy foods that can tackle protein energy malnutrition and the management of diseases. Kumar et al. [10] summarized anti-nutritional compounds present in different pulses including their fractions, significance, and beneficial and adverse effects on human health.

Moreover, the time series analysis of pulses has a significant role for the prediction of future growth pattern based on the past and present trends. Considering this fact, various researchers analyzed the growth rate and instability in pulses for various geographical regions. Sharma et al. [11] examined the growth and trend of pulse production in India using time series data on area, production, yield, and trade pertaining to the period 1980-81 to 2008-09. Chatterjee et al. [12] evaluated the overall trend in area, production, and productivity of kharif, rabi, and total pulses as well as their respective growth rates and instability during the period 1986-87 to 2007-08 for the sixteen major pulse growing states of India. Kumar et al. [13] evaluated the compound growth rate and carried out decomposition analysis of pulses production in India. Sood et al. [14] examined the growth performance and instability of pulses in the state of Rajasthan. Akah et al. [15] studied pulse production, consumption and utilization in Nigeria, and evaluated growth rates in area, production and yield of cowpea in Nigeria and other major regions during the period (1996-98 to 2016-2018). Sonawane et al. [16] investigated the region-wise performance of chickpea on the basis of growth and instability in Maharashtra state of India. Balai et al. [17] reported the growth, decomposition and instability in area, production and productivity of rabi pulse crops viz., gram and lentil in Madhya Pradesh. Some other remarkable contributions towards time series analysis of crops, other than pulses, have been made by Kumar and Menon [18], Rana and Kumar [19], Kumar et al. [20], and Prakash et al. [21].

The objective of the present paper is to carry out comparative assessment of the instability and growth rate in area, production, and yield of major pulses (viz., chickpea, pigeon pea, urdbean, and mungbean) in India. The analysis is made by computing statistical measures viz., Cuddy-Della Valle (CDV) instability indices and compound growth rates (CGRs) concerning three periods, viz., Period-I (2000-2010), Period-II (2011-2021) and the overall period (2000-2021).

2. MATERIALS AND METHODS

In the present analysis, the secondary time series data on area, production, and yield of major pulses (i.e., chickpea, pigeon pea, urdbean and mungbean) in India pertaining to the period 2000 to 2021 is utilized. The study period is classified into three periods i.e. period-I (2000 to 2010), period-II (2011 to 2021), and the overall period (2000 to 2021). The concerned time series data is obtained from the Directorate of Economics & Statistics, DAC&FW, Govt. of India and ICAR-Indian Institute of Pulses Research, India.

Significant variations are observed in the area, production, and yield of pulses considered under investigation during the concerned periods of study. To examine these variations,the Cuddy-Della Valle (CDV) instability index and compound growth rate (CGR) are computed.

The Cuddy-Della Valle (CDV) instability index is given by

$$I = CV\sqrt{1 - R^2}$$

where R^2 denotes the coefficient of determination, which is obtained on fitting linear

model to the concerned time series data on area, production, and yield of pulses. Also, CV represents the coefficient of variation.

The compound growth rate (CGR) in area, production and yield of pulses is obtained on using the following function:

$$y_t = y_0(1+r)^t$$

where
y_t = observed time series value of area, production, or yield (as the case may be) of pulses at time t
y_0 = initial time series value of area, production, or yield
r = compound growth rate.

Here, the compound growth rate (r) is measured in terms of percentage as follows:

$$r = \left[\left(\frac{y_t}{y_0}\right)^{1/t} - 1\right] \times 100$$

3. RESULTS AND DISCUSSION

The secondary time series data on area, production, and yield of major pulses (viz., chickpea, pigeon pea, urdbean, and mungbean) in India pertaining to the period 2000 to 2021 is elaborated in Table1. Moreover, the values of various statistical coefficients, i.e., coefficient of variation (CV), coefficient of determination (R^2), and Cuddy-Della Valle instability index (I) for area, production, and yield of pulses in India are depicted in Tables 2, 3, and 4 respectively. The values of R^2 are obtained on fitting linear models to the respective time series data on area, production, and yield of pulses in India. Furthermore, the compound growth rates (CGRs) are computed for area, production, and yield of pulses in India, and the findings are summarized in Table 5.

The Table 2 reveals that there is a significant increase in instability in area of chickpea, pigeon pea, and urdbean in period-II as compared to the period-I. However, there is a slight decline in instability in area of mungbean in period-II as compared to period-I. The highest transition of instability in area among the selected pulses is observed in urdbean (i.e., 5.53%), as the instability in area under urdbean was 6.83% in the period-I, which was increased to 12.36% in period-II. During the overall period, the instability in area of urdbean is observed to be the highest (i.e., 14.09%), followed by other pulses, i.e., mungbean (i.e., 11.74%), pigean pea (i.e., 7.76%), and chickpea (i.e., 6.42%).

Moreover, from Table 3, it is revealed that there is a significant increase in instability in production of chickpea, pigeon pea, and urdbean in period-II as compared to the period-I. However, there is a significant decline in instability in production of mungbean in period-II as compared to the period-I. During the overall period, the instability in production of mungbean is observed to be the highest (i.e., 23.34%), followed by other pulses, i.e., urdbean (i.e., 21.19%), pigean pea (i.e., 15.29%), and chickpea (i.e., 11.98%).

Furthermore, Table 4 exhibits that there is a slight increase in instability in the yield of chickpea, pigeon pea, and urdbean in period-II as compared to the period-I. However, there is a significant decline in instability in yield of mungbean in period-II as compared to period-I. During the overall period, the instability in yield of mungbean is observed to be the highest (i.e., 15.74%), followed by other pulses, i.e., pigean pea (i.e., 9.71%), urdbean(i.e., 8.98%), and chickpea (i.e., 7.37%).

It is revealed from Table 5 that there is a significant positive growth rate in area of urdbean during period-II (i.e., 3.46%) as compared to the period-I (i.e., 0.80%), whereas there is a significant decline in growth rate in area of chickpea during period-II (i.e., 2.77%) as compared to the period-I (i.e., 5.88%). The growth rate in area of pigeon pea is slightly high in period-II (i.e., 2.33%) as compared to period-I (i.e., 1.87%). The growth rate in area of mungbean is slightly higher in period-II (i.e., 3.21%) as compared to period-I (i.e., 1.66%). During the overall period, the growth rate in area of chickpea is observed to be the highest (i.e., 3.60%), followed by other pulses, i.e., mungbean (i.e., 2.15%), urdbean (i.e., 2.08%), and pigeon pea (i.e., 1.58%).

Among the pulses, the growth rates in production are significantly high for pigeon pea and urdbean in period-II as compared to period-I. However, significant decline in growth rates of production of chickpea and mungbean are observed during period-II as compared to the period-I. The overall period witnessed a significant positive growth rate in production of chickpea (i.e., 6.24%), whereas similar pattern of growth rates are observed in production of pigeon pea (i.e., 3.18%), urdbean (i.e., 3.72%), and mungbean (i.e., 3.21%).

Table 1. Time series data on area, production, and yield of major pulses in India

	Chickpea			Pigeon Pea			Urdbean			Mungbean		
Year	**A**	**P**	**Y**	**A**	**P**	**Y**	**A**	**P**	**Y**	**A**	**P**	**Y**
2000	5.19	3.86	0.74	3.63	2.25	0.62	3.01	1.29	0.43	3.01	1.03	0.34
2001	6.42	5.47	0.85	3.33	2.26	0.68	3.30	1.50	0.45	3.09	1.11	0.36
2002	5.91	4.24	0.72	3.36	2.19	0.65	3.55	1.47	0.41	3.01	0.87	0.29
2003	7.05	5.72	0.81	3.52	2.36	0.67	3.42	1.47	0.43	3.55	1.71	0.48
2004	6.71	5.47	0.82	3.52	2.35	0.67	3.17	1.33	0.42	3.34	1.06	0.32
2005	6.93	5.60	0.81	3.58	2.74	0.77	2.94	1.23	0.42	3.11	0.95	0.31
2006	7.49	6.33	0.85	3.56	2.31	0.65	3.07	1.44	0.47	3.19	1.12	0.35
2007	7.54	5.75	0.76	3.73	3.08	0.83	3.19	1.46	0.46	3.73	1.52	0.41
2008	7.89	7.06	0.89	3.38	2.27	0.67	2.67	1.17	0.44	2.84	1.03	0.36
2009	8.17	7.48	0.92	3.47	2.46	0.71	2.96	1.24	0.42	3.07	0.69	0.22
2010	9.19	8.22	0.89	4.37	2.86	0.65	3.26	1.76	0.54	3.55	1.80	0.51
2011	8.30	7.70	0.93	4.01	2.65	0.66	3.30	1.77	0.54	3.43	1.63	0.48
2012	8.52	8.83	1.04	3.89	3.02	0.78	3.19	1.90	0.60	2.75	1.19	0.43
2013	9.93	9.53	0.96	3.90	3.17	0.81	3.06	1.70	0.56	3.38	1.60	0.47
2014	8.25	7.33	0.89	3.85	2.81	0.73	3.24	1.96	0.60	3.02	1.50	0.50
2015	8.40	7.06	0.84	3.96	2.56	0.65	4.01	2.19	0.55	3.83	1.60	0.42
2016	9.63	9.38	0.97	5.34	4.87	0.91	4.50	2.83	0.63	4.32	2.17	0.50
2017	10.56	11.38	1.08	4.44	4.29	0.97	5.44	3.56	0.65	4.26	2.01	0.47
2018	9.55	9.94	1.04	4.55	3.32	0.73	4.83	3.36	0.70	4.25	2.41	0.57
2019	9.70	11.08	1.14	4.53	3.89	0.86	4.53	2.53	0.56	4.58	2.51	0.55
2020	10.00	11.91	1.19	4.72	4.32	0.92	4.14	2.23	0.54	5.13	3.09	0.60
2021	10.91	13.75	1.26	5.05	4.34	0.86	4.64	2.78	0.60	4.70	2.00	0.43

Note: *A = Area (in Million Hectares), P = Production (in Million Tons), and Y = Yield (in Tons / Hectare).*

(***Sources:*** *Directorate of Economics & Statistics, DAC&FW, Govt. of India, and ICAR-Indian Institute of Pulses Research, India.*

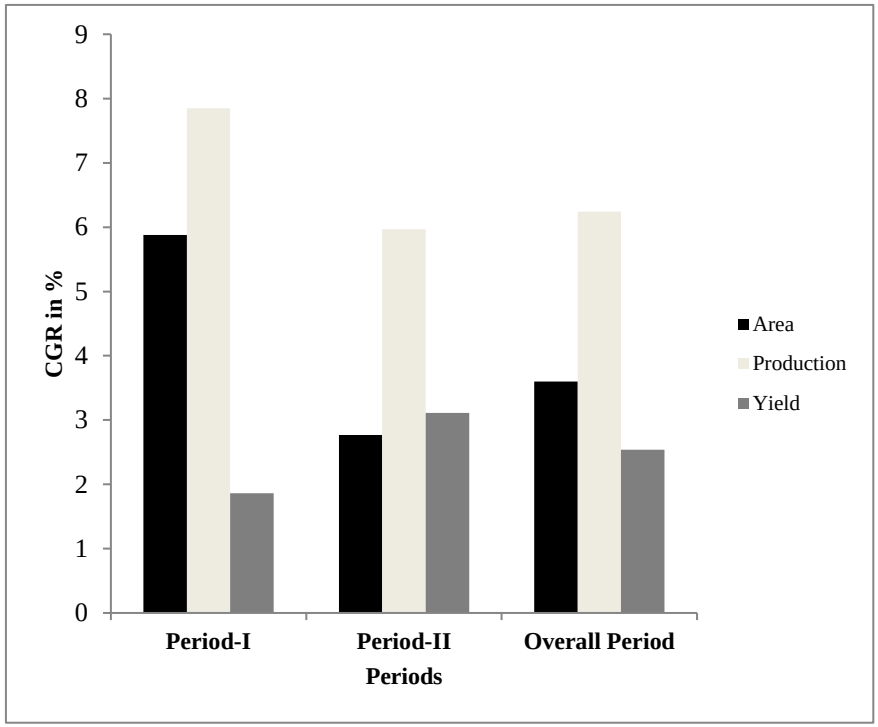

Fig. 1. Period-wise compound growth rate in area, production, and yield of chickpea in India

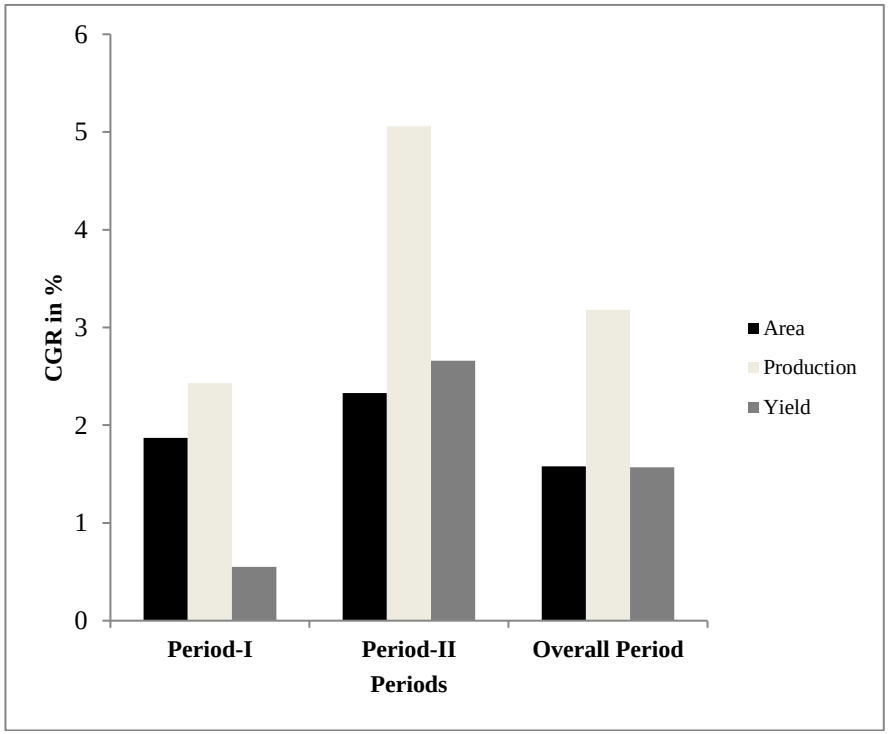

Fig. 2. Period-wise compound growth rate in area, production, and yield of pigeon pea in India

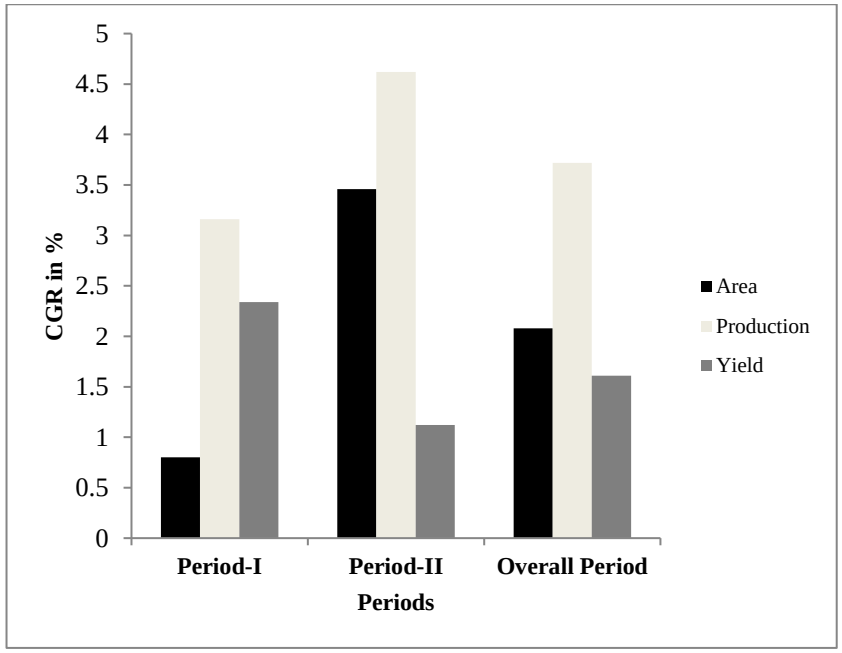

Fig. 3. Period-wise compound growth rate in area, production, and yield of urdbean in India

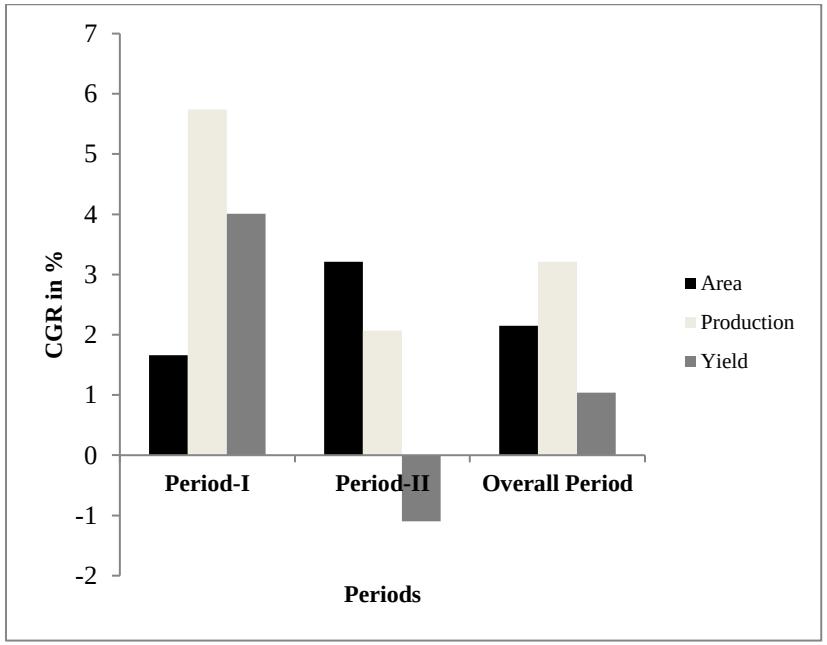

Fig. 4. Period-wise compound growth rate in area, production, and yield of mungbean in India

Table 2. Values of various statistical coefficients for area of pulses

	Period-I (2000-2010)			Period-II (2011-2021)			Overall Period (2000-2021)		
Pulses	**C.V.**	R^2	**I**	**C.V.**	R^2	**I**	**C.V.**	R^2	**I**
Chickpea	14.75	0.90	4.69	9.44	0.55	6.31	18.18	0.88	6.42
Pigeon Pea	7.61	0.25	6.57	11.10	0.53	7.63	14.09	0.70	7.76
Urdbean	7.47	0.16	6.83	18.49	0.55	12.36	20.22	0.51	14.09
Mungbean	8.24	0.06	7.97	17.97	0.81	7.74	18.17	0.58	11.74

Table 3. Values of various statistical coefficients for production of pulses

	Period-I (2000-2010)			Period-II (2011-2021)			Overall Period (2000-2021)		
Pulses	**C.V.**	R^2	**I**	**C.V.**	R^2	**I**	**C.V.**	R^2	**I**
Chickpea	20.87	0.83	8.59	20.26	0.67	11.55	32.41	0.86	11.98
Pigeon Pea	11.34	0.32	9.36	21.44	0.49	15.36	26.41	0.66	15.29
Urdbean	11.40	0.01	11.36	24.75	0.39	19.40	35.59	0.65	21.19
Mungbean	28.62	0.04	28.04	26.46	0.63	16.10	37.80	0.62	23.34

Table 4. Values of various statistical coefficients for yield of pulses

	Period-I (2000-2010)			Period-II (2011-2021)			Overall Period (2000-2021)		
Pulses	**C.V.**	R^2	**I**	**C.V.**	R^2	**I**	**C.V.**	R^2	**I**
Chickpea	7.45	0.47	5.41	11.93	0.61	7.42	15.18	0.76	7.37
Pigeon Pea	8.22	0.11	7.76	12.50	0.32	10.29	13.50	0.48	9.71
Urdbean	7.90	0.24	6.90	8.29	0.05	8.08	16.22	0.69	8.98
Mungbean	21.55	0.02	21.33	11.48	0.18	10.37	21.98	0.49	15.74

Table 5. Compound Growth Rates (CGRs) for area, production and yield of pulses

	Period-I (2000-2010)			Period II (2011-2021)			Overall Period (2000-2021)		
Pulses	**A**	**P**	**Y**	**A**	**P**	**Y**	**A**	**P**	**Y**
Chickpea	5.88	7.85	1.86	2.77	5.97	3.11	3.60	6.24	2.54
Pigeon Pea	1.87	2.43	0.55	2.33	5.06	2.66	1.58	3.18	1.57
Urdbean	0.80	3.16	2.34	3.46	4.62	1.12	2.08	3.72	1.61
Mungbean	1.66	5.74	4.01	3.21	2.07	-1.10	2.15	3.21	1.04

Among the pulses, the growth rates in yield of chickpea and pigeon pea are observed to be slightly high during period-II as compared to period-I, whereas a slight decline in growth rate of yield of urdbean is observed in period-II as compared to period-I. A positive and high growth rate in yield of mungbean is observed in period-I (i.e., 4.01%), whereas a negative and least growth rate in yield of mungbean is observed in period-II (i.e., -1.10%). The overall period witnessed a positive and high growth rate in yield of chickpea (i.e., 2.54%), whereas similar pattern of growth rates are observed in yield of pigeon pea (i.e., 1.57%), urdbean (i.e., 1.61%), and mungbean (i.e., 1.04%).

The period-wise compound growth rates (CGRs) in area, production, and yield of major pulses (viz., chickpea, pigeon pea, urdbean, and mungbean) in India are depicted graphically in Figs. 1 to 4.

4. CONCLUSION

In the present analysis, the comparative assessment of instability and growth rate in area, production, and yield of major pulses (viz., chickpea, pigeon pea, urdbean and mungbean) in India is carried out by considering three periods, viz., Period-I (2000-2010), Period-II (2011-2021) and the overall period (2000-2021). The level of instability in pulses is measured during the concerned periods using Cuddy-Della Valle (CDV) instability index. Moreover, the compound growth rates (CGRs) in area, production, and yield of pulses are computed during the concerned periods of investigation.

In India, chickpea reported a significant rise in instability in area, production, and yield during period-II as compared to period-I. A similar pattern of rise in instability is revealedin area, production, and yield of pigeon pea and urdbean. Moreover, mungbean witnessed a decline in instability in area, production, and yield during period-II as compared to period-I. During the overall period, the highest instability in production and yield is observed in mungbean as compared to the other pulses. Moreover,highest instability in area is observed in urdbean as compared to the other pulses. Furthermore, chickpea reported least instability in area, production, and yield during the entire period of investigation.

During period-II, a significant risein growth rate of area is observed in pigeon pea, urdbean, and mungbean as compared to period-I. Moreover, a significant rise in production is revealed in pigeon pea and urdbean. Furthermore, significant rise in yield is exhibited in chickpea and pigeon pea. During the overall period, the growth rate in area, production, and yield of chickpea was observed to be the highest as compared to other pulses.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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