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Growth and instability in area, production, productivity and export of millets in India

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Abstract
Millets, traditionally cultivated and consumed across India, have long played a crucial role in ensuring food and nutritional security, particularly in arid and semi-arid regions. However, following the Green Revolution, the area under millet cultivation drastically declined due to increased focus on high-yielding varieties of rice and wheat, extensive irrigation development, and changes in consumption patterns. Recognizing their resilience, low input requirements, and superior nutritional profile, the Government of India rebranded millets as “Nutri-Cereals” and has since undertaken various initiatives to promote their production and global outreach. Against this backdrop, the present paper highlights the growth and instability in area, production, productivity and export of major millets such as Bajra (Pearl Millet), Ragi (Finger Millet), and Jowar (Sorghum) in India over the ten-year period from 2014–15 to 2023–24. Trend analysis shows mixed patterns across millets. Bajra had stable area (CAGR: 0.0%) with rising production (2.8%) and yield (2.6%). Ragi showed stagnation in area (0.0%) and slight decline in production (-0.1%) and yield (-0.2%). Jowar saw sharp area decline (-5.81%) but strong yield growth (4.71%). Export trends revealed a significant fall in Bajra export quantity (CAGR: -9.84%) and moderate decline in value (-5.59%). Ragi exports grew notably value (17.76%) and quantity (12.46%). Jowar exports showed declining quantity (-10.87%) but moderate value growth (5.93%). Over a decade, Bajra showed stable area (CV: 3.43%, CDVI: 3.41%), moderate yield (CV: 9.19%, CDVI: 4.61%) and production (CV: 10.74%, CDVI: 6.83%). Exports were unstable value (₹4124.15 lakhs, CV: 28.52%, CDVI: 23.61%), quantity (15,487 MT, CV: 36.44%, CDVI: 22.10%). Ragi showed moderate instability in area (1120.6 '000 ha, CDVI: 9.75%), yield (1541.8 kg/ha, CDVI: 9.65%), and higher in production (1730.7 '000 tonnes, CDVI: 14.99%). Exports were highly unstable value (₹2409.88 lakhs, CDVI: 45.59%), quantity (10,496.71 MT, CDVI: 54.44%). Jowar showed high instability in area (CDVI: 34.54%), production (44.20%), and moderate in yield (19.71%).

Keywords: Bajra, Ragi, Jowar, area, production, productivity, export, compound annual growth rate, instability

Introduction
Millets are a group of small-grained cereal crops that are highly nutritious and thrive in marginal or low-fertility soils with minimal use of fertilizers and pesticides. These hardy crops play a vital role in ensuring food and nutritional security, particularly in rain-fed and resource-poor regions. Most millet varieties are indigenous to India and are often referred to as "Nutri-cereals" due to their rich nutrient content, essential for maintaining human health. Grown predominantly in areas with low rainfall, millets are crucial for promoting sustainable agriculture and long-term food security. Based on the area under cultivation and grain size, millets are classified into two categories: major and minor millets. Major millets include sorghum (jowar) and pearl millet (bajra), while minor millets encompass finger millet (ragi/mandua), foxtail millet (kangni), little millet (kutki), kodo millet, barnyard millet (sawan/jhangora), proso millet (cheena), and browntop millet (korale).

In India, millets were traditionally an integral part of the diet and agricultural practices. However, the emphasis on food security during the Green Revolution in the 1960s led to a policy and research focus on high-yielding varieties of wheat and rice. Consequently, millets were marginalized and came to be referred to as "orphan crops," with their cultivation and consumption experiencing a significant decline.

Prior to the Green Revolution, millets accounted for approximately 40% of the total grain cultivation in the country; this share has since reduced to nearly 20%, raising concerns regarding their implications for agricultural sustainability, nutritional security, and environmental resilience.
The objectives of the study include to analyse the growth and instability in area, production, productivity and export of millets (bajra, ragi and jowar) from India.

Methodology
The data regarding area, production, yield, export quantity and export value of millets such as Bajra (10082120), Ragi (10082130) and Jowar (10082110) in India is collected from 2014-15 to 2023-24 which includes 10 years data from different sources like Agricultural Processed Food Product Export Development Authority (APEDA), Directorate General of Commercial Intelligence and Statistics (DGCIS), Indiastat.com, etc.

Growth rate analysis
The growth in area, production, productivity and export can be examined by using the Compound annual growth rate (CAGR). This can be done by fitting the exponential function given below:

$Y = a.b^t e_i$ ..... (1)

Where, Y = Depended variable for which growth rate is to be estimated (Quantity exported / export value / unit value)
a = Intercept
b = Regression Coefficient
t = Time Variable.
This equation was estimated after transforming (1) as follows,

Log y = log a + t Log b ..... (2)

Then the percent compound growth rate (g) was computed using the relationship.

CAGR (g) = (antilog b –1) ×100 ..... (3)

SThe significance of the regression coefficient was tested using the student 't' test.

Degree of instability
To study variability in area, production, productivity and export of guava an instability index was used as a measure of variability. The degree of instability in area, production, yield, export quantity and export value of guava was measured by using coefficient of variation and Cuddy-Della Valle Index.

Coefficient of variation (CV)
Coefficient of variation = $\sigma/\bar{X}\times100$
Where, σ = Standard deviation,
$\bar{X}$ = Arithmetic mean

Cuddy-Della Valle's Instability Indices (CDVI)
The Cuddy-Della Valle Instability Index was employed to measure the instability of area, production, productivity and export data. This index is an adjusted form of the coefficient of variation (CV), specifically designed to account for trends commonly observed in economic time series data.
Instability Index = CV $\sqrt{1 - adjR^2}$
Where, CV = coefficient of variation
$adjR^2$ = Coefficient of determination

Results and Discussion
Growth and instability in area, production and productivity of millets in India
The growth performance of Millets (Bajra, Ragi and Jowar) in India, in terms of area, production, and productivity, was examined using the Compound Annual Growth Rate (CAGR) methodology. The extent of instability in the area, production, and productivity of millets (bajra, ragi and jowar) cultivation in India. To assess these fluctuations, two statistical tools were used the Coefficient of Variation (CV) and Cuddy-Della Valle's Instability Index.

Growth and instability in area, production and productivity of bajra in India
The table no. 1 shows the analysis of Bajra cultivation in India over the study period reveals that the area under cultivation remained largely unchanged, with a CAGR of 0.000%, a t-value of 0.28, and a p-value of 0.79 indicating no statistically significant growth. In contrast, production showed a meaningful increase, growing at a CAGR of 2.80%, supported by a t-value of 3.36 and a statistically significant p-value of 0.010. Productivity improved even more notably, with the highest growth rate at 2.57% CAGR and a strong t-value of 4.7 (p = 0.002), reflecting a consistent and significant upward trend.
In terms of instability, the area under cultivation was quite stable, with a low coefficient of variation (CV) of 3.43% and a CDVI of 3.41%. Production showed moderate fluctuations (CV: 10.74%, CDVI: 6.83%), while productivity remained relatively stable in comparison, with a CV of 9.19% and a CDVI of 4.61%. These findings aligned with the early study by Yamuna *et al.* (2024) [3].

Table 1: Growth and instability in area, production and productivity of bajra in India

Particulars		Area	Production	Productivity
Growth	't' Value	0.28	3.36	4.7
	CAGR (%)	0.000	2.80**	2.57***
	p- value	0.79	0.010	0.002
Instability	CV	3.43	10.74	9.19
	CDVI	3.41	6.83	4.61

Note: * Significant at 10% level ($p< 0.10$),
** Significant at 5% level ($p< 0.05$),
*** Significant at 1% level ($p< 0.01$)

Growth and instability in area, production and productivity of Ragi in India
The table 2 shows the analysis of Ragi in India indicates that there was no significant growth in its cultivation over the study period. The area under cultivation showed a minor increase (CAGR: 0.69%), but this was statistically insignificant, as reflected by a t-value of 0.57 and a p-value of 0.58. Production declined slightly (CAGR: -0.68%), though the trend was not statistically meaningful (t = -0.33, p = 0.75). Similarly, productivity saw a moderate drop (CAGR: -1.37%), but with a t-value of -1.16 and a p-value of 0.28, this decline also lacked statistical significance.
In terms of instability, the area under Ragi cultivation experienced moderate variation, with a coefficient of variation (CV) of 9.97% and a CDVI of 9.75%. Production showed the highest fluctuation (CV: 15.18%, CDVI: 14.99%), suggesting year-to-year inconsistencies. Productivity, while declining,

showed moderate variability with a CV of 10.41% and a CDVI of 9.65%. These findings aligned with the early study by Chaitra *et al.* (2024) [1].

Table 2: Growth and instability in area, production and productivity of Ragi in India

Particulars		Area	Production	Productivity
Growth	't' Value	0.57	-0.33	-1.16
	CAGR (%)	0.69	-0.68	-1.37
	p- value	0.58	0.75	0.28
Instability	CV	9.97	15.18	10.41
	CDVI	9.75	14.99	9.65

Growth and instability in area, production and productivity of Jowar in India

The table 3 shows the analysis of Jowar cultivation in India reveals a significant decline in area, with a CAGR of -5.81%, a strong t-value of -6.134, and a p-value of 0.001, indicating a highly significant downward trend. While production also declined (CAGR: -1.37%), the change was not statistically significant (t = -0.893, p = 0.398). In contrast, productivity showed a statistically significant improvement, growing at a CAGR of 4.71%, with a t-value of 4.672 and a p-value of 0.002.

In terms of instability, area showed the highest year-to-year variation, with a CV of 19.81%, though the CDVI was relatively lower at 8.09%, suggesting a consistent long-term trend. Production had moderate instability (CV: 12.72%, CDVI: 12.03%), while productivity displayed noticeable fluctuations (CV: 15.56%) but was relatively stable in trend terms (CDVI: 7.51%).

Table 3: Growth and instability in area, production and productivity of Jowar in India

Particulars		Area	Production	Productivity
Growth	't' Value	-6.134	-0.893	4.672
	CAGR (%)	-5.81	-1.37	4.71***
	p- value	0.001	0.398	0.002
Instability	CV	19.81	12.72	15.56
	CDVI	8.09	12.03	7.51

Note: *** Significant at 1% level ($p< 0.01$)

CV- Coefficient of Variation, CDVI- Cuddy- Della Valle's Instability Index

Growth and instability in Export quantity and value of millets from India

Growth and instability in Export quantity and value of Bajra from India

The export performance of bajra from India showed a significant decline in quantity, with a CAGR of -9.84%, a t-value of -4.10, and a p-value of 0.003, indicating strong statistical significance. The export value also declined at a CAGR of -5.59%, with a t-value of -2.17 and a p-value of 0.061, suggesting a moderate but less statistically significant downward trend.

In terms of instability, export quantity was highly volatile, with a CV of 65.03% and a CDVI of 54.44%, pointing to considerable year-to-year fluctuations. Similarly, export value showed high instability (CV: 60.76%, CDVI: 45.59%), reflecting inconsistent performance in global markets over the period.

Table 4: Growth and instability in Export quantity and value of Bajra from India

Particulars		Export quantity	Export value
Growth	't' Value	-4.10	-2.17
	CAGR (%)	-9.84**	-5.59*
	p- value	0.003	0.061
Instability	CV	65.03	60.76
	CDVI	54.44	45.59

Growth and instability in Export quantity and value of Ragi from India

Ragi exports from India have shown encouraging growth, especially in terms of value. The export value increased significantly at a CAGR of 17.76%, with statistical support from a t-value of 2.80 and a p-value of 0.023. Although the export quantity also grew, with a CAGR of 12.46%, the increase was not statistically significant (t = 1.63, p = 0.14).

However, this growth came with considerable fluctuations. Both export quantity and value experienced high year-to-year variability. The quantity had a CV of 65.03% and a CDVI of 54.44%, while the value showed a CV of 60.76% and CDVI of 45.59%. These figures indicate that while Ragi exports have grown, they have not been stable or consistent over time.

Table 5: Growth and instability in Export quantity and value of Ragi from India

Particulars		Export quantity	Export value
Growth	't' Value	1.63	2.80
	CAGR (%)	12.46	17.76 ***
	p- value	0.14	0.023
Instability	CV	65.03	60.76
	CDVI	54.44	45.59

Growth and instability in Export quantity and value of Jowar from India

India's Jowar exports have shown a declining and inconsistent trend over the study period. The export quantity fell sharply, with a negative growth rate of -10.87%, though this decline was not statistically significant. In contrast, the export value increased modestly at 5.93% CAGR, but this growth was also not statistically meaningful.

Export quantity was extremely volatile, with a coefficient of variation (CV) of 96.14% and a Cuddy-Della Valle Index (CDVI) of 76.85%, indicating large year-to-year fluctuations. Export value was also highly unstable, with a CV of 57.77% and CDVI of 56.89%. These findings suggest that Jowar exports have lacked consistency, making them unreliable both in terms of volume and value. These results are correlated with previous study by Kumudha (2024) [2].

Table 6: Growth and instability in Export quantity and value of Jowar from India

Particulars		Export quantity	Export value
Growth	't' Value	-1.048	0.631
	CAGR (%)	-10.87	5.93
	p- value	0.325	0.546
Instability	CV	96.14	57.77
	CDVI	76.85	56.89

Conclusion

The analysis of growth and instability in the area, production, productivity, and export performance of Bajra, Ragi, and Jowar in India reveals a diverse pattern of trends. Bajra exhibited a stagnant growth in area (CAGR: 0.00%, t = 0.28, p = 0.79), but

its production and productivity recorded statistically significant positive growth at 2.80% (t = 3.36, p = 0.010) and 2.57% (t = 4.7, p = 0.002), respectively. Instability in Bajra's indicators was relatively low, with CVs ranging from 3.43% to 10.74% and CDVIs from 3.41 to 6.83, suggesting a stable domestic performance. On the other hand, Ragi did not show any statistically significant growth in area (CAGR: 0.69%, t = 0.57), production (CAGR: -0.68%, t = -0.33), or productivity (CAGR: -1.37%, t = -1.16), with p-values well above the 0.05 threshold. Moderate levels of instability (CV: 9.97–15.18%, CDVI: 9.65–14.99) were observed, indicating fluctuations but without significant long-term directional change. Jowar demonstrated a sharp and statistically significant decline in area (CAGR: -5.81%, t = -6.13, p = 0.001), an insignificant decline in production (CAGR: -1.37%, t = -0.893), and a significant rise in productivity (CAGR: 4.71%, t = 4.672, p = 0.002). However, instability remained pronounced, especially in area (CV: 19.81%, CDVI: 8.09%).

From an export perspective, Bajra recorded a statistically significant decline in export quantity (CAGR: -9.84%, t = -4.10, p = 0.003) and a moderate decline in value (CAGR: -5.59%, t = -2.17, p = 0.061), both coupled with high instability (CV: 60.76–65.03%, CDVI: 45.59–54.44). In contrast, Ragi's export value showed significant positive growth (CAGR: 17.76%, t = 2.80, p = 0.023), while export quantity increased moderately (CAGR: 12.46%, t = 1.63, p = 0.14). Nonetheless, these exports were highly unstable, as indicated by similar CV and CDVI ranges. Jowar’s exports faced the steepest decline in quantity (CAGR: -10.87%, t = -1.048) and a modest, statistically insignificant growth in value (CAGR: 5.93%, t = 0.631), with very high levels of instability (CV: 57.77–96.14%, CDVI: 56.89–76.85). The results indicate that while Bajra has experienced notable gains in production and productivity, and Ragi has shown promise in export value, the millet sector as a whole remains constrained by high volatility and declining trends in cultivation area and export volumes, particularly in the case of Jowar.

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