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Growth and trends of pigeonpea (*Cajanus cajan*) in Uttar Pradesh state

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ABSTRACT

The present study evaluated the growth performance of area, production and yield of pigeonpea (*Cajanus cajan* L. Millsp.) in different districts as well as agroclimatic zones of Uttar Pradesh. The study used time series data of 25 years i.e. from 1997–98 to 2022–23. Emphasising the role of National Food Security Mission (NFSM) on pulses production, the entire study period was divided into two sub-periods; sub-period I: 1997–98 to 2007–08 (Pre NFSM) and sub-period II: 2007–08 to 2022–23 (Post NFSM). Compound annual growth rate was used to study the growth rate in area, production and yield for all the districts. Among the agroclimatic zones, Bundelkhand zone and Vindhyan zone were found to be efficient zones showing positive growth rate in area and production. Further in post NFSM period, majority of the districts were observed to be showing positive growth rate in yield which can be attributed to the enhanced input supply and advanced technologies introduced through this programme. The pre and post NFSM comparative analysis clearly depicted the role of improved production technologies and knowledge dissemination through extension activities under programme in the improved pigeonpea production scenario in different agroclimatic zones of Uttar Pradesh. Being among the major pigeonpea producing states, targeted policy interventions under various programmes should focus on districts showing high yield growth rates for maximising production of the state, paving towards achieving pulse self-sufficiency in India.

Keywords: Agroclimatic zones, Growth rate, NFSM, Pigeonpea

Being major source of protein, the majority of the people in India take pulses in daily diet along with cereals. They help not only in maintaining heart health, proper digestion, and blood sugar level of humans (Gopalan *et al.* 1989, Singh 2017), but also help in sustainable agriculture, enhancing soil fertility and reducing greenhouse gas emissions (FAOSTAT 2024). The majority of pulses are cultivated in rainfed regions that are resource-limited, environmentally harsh, and often subjected to drought and other abiotic stress conditions (Hazra and Basu 2023). Increase in pulse production is required to maintain nutritional security in India (Sah *et al.* 2024). Ahmad *et al.* (2018) showed production of pulses went up from 2.99% in TE-2003 to 6.22% in TE-2016 at eastern India. To fulfil the production challenges, the Government of India has undertaken several policy initiatives aiming at enhancing pulse productivity and ensuring self-sufficiency. Notable among these were the Technology Mission on Pulse Production (TMPP) launched in 1986–87 and the National Food Security Mission (NFSM) initiated in 2006–07 both of which have provided significant incentive to boost domestic pulse production. Third advance estimates for 2023–24 indicated that the total pulse production in India is 23.44 million tonnes which is higher by 1.40 million tonnes than the last five years average (DAC and FW 2023). Despite the increase in average pulse production, India still partially relies on imports to meet its substantial domestic demand. Merely increasing the area and production may not completely resolve this issue; hence, the identification of regions with higher growth potential, where technological interventions can be made, is of utmost importance.

Pigeonpea (*Cajanus cajan* L. Millsp.) is an important pulse crop, cultivated over an area of 4.07 million hectares, with a production of 3.31 million tonnes in India during 2022–23. Uttar Pradesh with 10.91% share in total pigeonpea production stands at third place after Maharashtra (27.94%) and Karnataka (25.83%). Uttar Pradesh covers approximately 7.3% and 12% of geographical and net cultivated area of the country, respectively and provides 21% total food grains, 18.5% pulses and 6% oilseeds (Kumar *et al.* 2018). It is the fourth largest as well as the most populous state in the country occupying 7.33% of the total area of the country with 199.8 million people (Agriculture Census 2011), accounting for 16.5% of India's total population. UP is fortunate to have the fertile Indo-Gangetic plains and, due to the vast size of the state's geographical area, it plays a major role in ensuring the nation's food security

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(Gulati *et al.* 2021). Pigeonpea, green gram [*Vigna radiata* (L.) Wilczek] and black gram [*Vigna mungo* (L.) Hepper] during *kharif* season and chick pea (*Cicer arietinum* L.), lentil (*Lens culinaris* Medik) and field pea (*Pisum sativum* L.) during *rabi* season are the important pulse crops in UP. Chickpea shares 31.4% of the total area under pulse cultivation in the state followed by lentil (21.5%), black gram/green gram (16.5%), pigeonpea (14.1%) and field pea (10.1%) (Kumar *et al.* 2023).

Pigeonpea is preferred over other pulses, accounting for about 34% of the total household expenditure on pulses in India (Vishwajith *et al.* 2018). Due to the high demand for pigeonpea dal coupled with limited availability, the price of pigeonpea has been increasing steadily. The area under pigeonpea cultivation in India is 0.35 million hectares, with a production of 0.36 million tonnes (DAC&FW 2023). India has to import pigeonpea to meet its domestic requirements. Therefore, there is an urgent need to identify potential regions for pigeonpea cultivation in Uttar Pradesh based on the growth rates of area, production, and productivity. With this background, present study was carried out to study the trend of area, production and yield of pigeonpea in UP state during 1997–2023 taking into account the variations in agroclimatic zones.

MATERIALS AND METHODS

The study was carried out during 2023–24 through which districtwise time series data of Uttar Pradesh (UP) for the period from 1997–98 to 2022–23 on area, production and yield of pigeonpea crop was collected from Directorate of Economics and Statistics, Department of Agriculture and Co-operation, Government of India, Directorate of Economics and Statistics, Government of Uttar Pradesh and Directorate of Pulse Development. The collected data were also compiled for the nine agro-climatic zones (ACZs) of Uttar Pradesh, viz. Bhabar and Tarai zone (I); Western Plain zone (II); Mid-Western Plain zone (III); South-Western Semi-Arid zone (IV); Central Plain zone (V); Bundelkhand zone (VI); North-Eastern Plain zone (VII); Eastern Plain zone (VIII) and Vindhyan zone (IX) (Supplementary Fig. 1). The whole data set (25 years) was divided into two sub-periods i.e. sub-period I: 1997–98 to 2007–08 (Pre NFSM) and sub-period II: 2007–08 to 2022–23 (Post NFSM). The agroclimatic zone and districtwise growth rate was calculated. A pictorial representation was also prepared for districtwise growth rate of UP using QGIS software.

Further, based upon growth rate in area and yield, a graph presenting districts under four quadrants namely Q1, Q2, Q3 and Q4 was also prepared. Area growth rate and production growth rate were taken on X-axis and Y-axis, respectively. Q1 takes positive growth rate values for both area and yield. Q2 takes positive growth rate values of yield and negative growth rate values of area. Q3 takes negative growth rate values for both area and yield. The last quadrant Q4 takes positive growth rate values of area and negative growth rate values of yield. The farther the growth rate position is from the origin, the higher the negative or positive values, depending on the quadrant, and vice versa.

Growth rate: The compound annual growth rate (CAGR) technique is the most widely used technique to calculate the growth rate (Patil *et al.* 2016, Joshi *et al.* 2021, Sah *et al.* 2022, nd Rani *et al.* 2024). The compound growth model is defined as follows.

$$Y_t = ab^t u_t$$

Where Y_t, Time series data on area/production/yield of pulse crops at time t; a and b, the parameters of the function to be estimated; u_t, Error term associated with model at time t; t, Time index (1, 2, 3,…, n).

The compound annual growth model was first linearised using natural logarithm and further estimates of the parameter a and b were obtained. Let $\breve{b}$ be the estimate of b. Compound Annual Growth Rate (CAGR) was calculated using:

$$r = (\text{anitlog } \breve{b} - 1) \times 100$$

In this study 'CompGR' (Udgata *et al.* 2024) CRAN package had been used to calculate growth rate for all the districts.

RESULTS AND DISCUSSION

Scenario of pulses in India: Table 1 displays the pulse area and production share of each major state in the country during 2022–23. Madhya Pradesh is the leading state, ranking first in both area (19.45%) and production (24.05%) of pulses, while Telangana ranks 10^{th}, accounting for 1.53% of the total area under pulse cultivation. Uttar Pradesh (UP) stands 4^{th} in area under total pulses (9.54%) with total production of 2.56 million tonnes (10.91%).

In India, pigeonpea represents a significant crop in terms of both acreage and production (Ansari *et al.* 2024). Total area under pigeonpea is around 4.07 million hectares all over India (Table 2). Maharashtra is the leading state in both area under pigeonpea (28.90%) and production (27.94%) with yield of 787 kg/ha. The states such as Gujarat, Uttar Pradesh, Jharkhand, Odisha and Tamil Nadu are having higher yield as compared to the national average. Uttar Pradesh occupies the third position in terms of area under pigeonpea cultivation and records a production of 0.36 million tonnes, which accounts for about 10.91% of the total pigeonpea production in India, with an average yield of 1,039 kg/ha.

Pulse scenario in Uttar Pradesh: Uttar Pradesh (UP) is a food bowl of India and provides both human resources and food resources due to the vast Indo Gangetic plains. UP state is home to five major pulse crops (Table 3). The area used for pulse cultivation (million hectares) has shown a steady, though somewhat fluctuating, increase from 1997–2023. While there were dips, particularly around 2002 and 2017 but the general trend was found to be upward. Pulse production (million tonnes) has also increased over time, although it showed more volatility compared to the area under cultivation. Sharp fluctuations can be observed,

Table 1 Major pulse growing states in India (2022–23)

State	Area (million ha)	India (% share)	Production (million tonnes)	India (% share)	Yield (kg/ha)
Madhya Pradesh	5.62	19.45	6.27	24.05	1,115
Maharashtra	4.99	17.28	4.64	17.79	928
Rajasthan	5.501	19.02	3.62	13.88	658
Uttar Pradesh	2.76	9.54	2.56	10.91	1,031
Gujarat	1.31	4.53	1.79	6.88	1,368
Karnataka	2.83	9.78	1.76	6.74	622
Andhra Pradesh	1.03	3.57	1.08	4.13	1,042
Jharkhand	0.73	2.52	0.76	2.92	1,048
Tamil Nadu	0.79	2.74	0.50	1.93	636
Telangana	0.44	1.53	0.50	1.91	1,122
All India	28.90	100	26.06	100	902

Source: Directorate of Economics and Statistics.

Table 2 Major pigeon pea growing states in India (2022–23)

State	Area (million ha)	India (% share)	Production (million tonnes)	India (% share)	Yield (kg/ha)
Maharashtra	1.18	28.90	0.93	27.94	787
Karnataka	1.22	29.90	0.86	25.83	701
Uttar Pradesh	0.35	8.60	0.36	10.91	1,039
Gujarat	0.24	5.99	0.28	8.56	1,163
Jharkhand	0.18	4.52	0.21	6.36	1,144
Telangana	0.23	5.63	0.20	6.10	882
Odisha	0.13	3.29	0.14	4.29	1,062
Madhya Pradesh	0.17	4.08	0.13	3.82	762
Andhra Pradesh	0.24	5.95	0.08	2.36	323
Tamil Nadu	0.04	1.07	0.05	1.37	1,039
All India	4.07	100	3.31	100	814

Source: Directorate of Economics and Statistics.

particularly in 2002, 2015, and 2020. Both the area and production trend lines (Fig. 1) had positive slopes, indicating positive growth over time. The slope of the area trend line (0.581) is higher than that of the production trend line (0.297), suggesting a faster growth rate in the pulses area than in production. Between 2003 and 2007, both area and production seemed relatively stagnant with minimal changes. The reasons for rise in area and production during 2016–2017 may be due to favourable government interventions, such as higher Minimum Support Prices (MSP), promotion under the National Food Security Mission (NFSM), and availability of improved high-yielding and short-duration varieties (NITI Aayog 2025). The subsequent increase after 2020 may be linked to enhanced irrigation coverage, increased adoption of improved pulse technologies, and the shifting of marginal lands from cereals to pulses due to better price realisation. However, the volatility reflects the dependence on monsoon rainfall, as mostly pulses are grown under rainfed condition in some parts of the state.

Districtwise growth performance of pigeonpea: Further, to identify the districtwise growth rate in pulse production in Uttar Pradesh, the Compound Annual Growth Rate (CAGR) was calculated for the period 1997–2023 (Fig. 2). According to their production CAGR values, districts of UP were

Table 3 Major pulse crops in Uttar Pradesh (2022–23)

Crop	Area (million hectare)	Production (million tonnes)	Yield (kg/ha)
Chickpea	0.68	0.90	1,321
Pigeonpea	0.35	0.36	1,039
Black gram	0.60	0.43	940
Lentil	0.54	0.52	950
Peas and other	0.46	0.71	154
Green gram	0.11	0.45	679

Source: Directorate of Economics and Statistics.

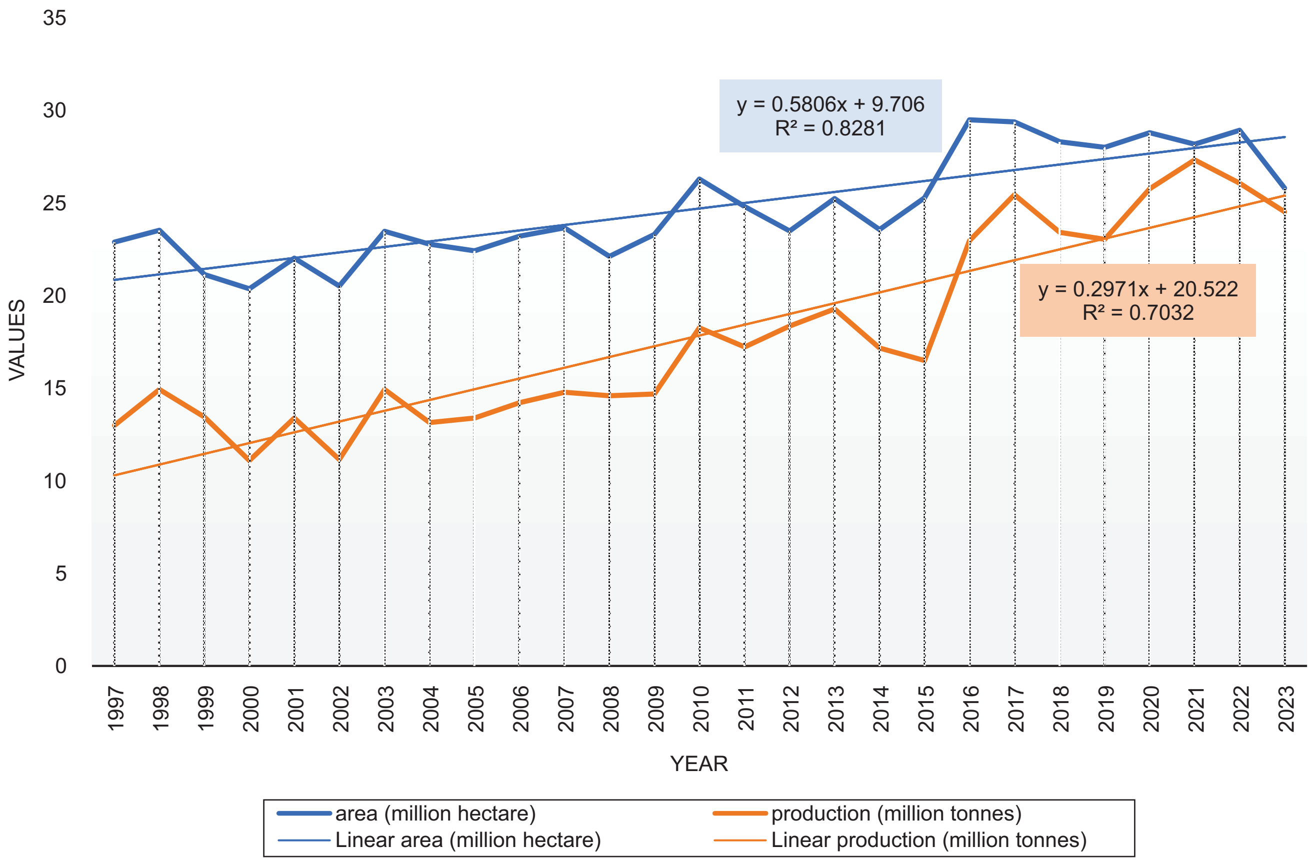

Fig. 1 Area and production scenario of total pulses in Uttar Pradesh.

categorised into eight classes. The districtwise growth rate in the state observed to vary in between -18.02% to 1.94%. Among districts witnessed positive growth rate in pigeonpea production, Firozabad ranked first with 1.94% growth rate followed by Ballia (1.12%), Baghpat (0.95%), Sonbhadra (0.86%), Jaunpur (0.66%), Sant Kabir Nagar (0.65%), Sant Ravidas Nagar (0.5%), Ghaziabad (0.35%), Saharanpur (0.22%), Azamgarh (0.22%), Ghazipur (0.10%), Banda (0.07%) and Mau (0.01%). Among the ten least-performing districts in terms of pigeonpea production, Barabanki had the smallest decline in growth rate (-7.21%), followed by Jhansi (-7.41%), Rampur (-7.62%), Lucknow (-7.75%), Agra (-9.77%), Bareilly (-10.16%), Lalitpur (-15.42%), Moradabad (-15.70%), Bijnor (-15.73%), and Pilibhit, which saw the steepest drop at -18.02%. Maximum districts lay in the category of negative growth rate with more than -3% (-3 to 0). Overall, majority of the districts showed a decrease in production of pigeonpea. Similar findings were also reported by Kumbhare *et al.* (2014), Nain *et al.* (2015), and Singh and Usami (2024) during the same period. The reasons behind the reduction in total production could be shift of cultivated area from pigeonpea to commercial crops such as sugarcane, vegetables, and oilseeds, erratic rainfall patterns, limited irrigation facilities, and the susceptibility of pigeonpea to pests and diseases (especially pod borer and wilt). Further, the slow adoption of improved varieties and delayed maturity might also have discouraged farmers from expanding pigeonpea cultivation.

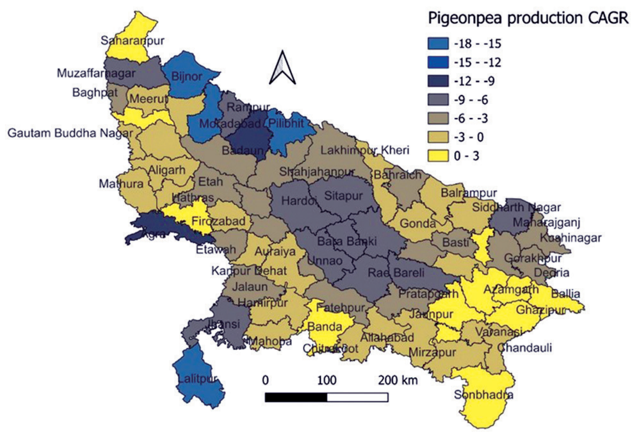

Fig. 2 Districtwise % growth rate of pigeonpea production in UP state (1997–2023).

Similarly, districtwise % growth rate in area and yield of pigeonpea for the time period 1997–2023 (Fig. 3) indicated that Ambedkar nagar, Ghazipur, Jaunpur, Amroha, Muzaffarnagar, Shahjahanpur and Mainpuri witnessed positive growth rate in area and yield. The highest growth rate in area can be observed in Muzaffarnagar (13.99%), whereas Mainpuri district witnessed the highest growth in yield (2.89%). In contrast, negative growth in both area and yield was observed in the districts such as Lucknow, Pratapgarh, Lalitpur, Mahoba, Kanpur Nagar, Kanpur Dehat, Balrampur, Agra, Hardoi, Unnao, Sitapur, Hardoi, Shravasthi, Faizabad, Deoria, Barabanki, Gonda, Kanpur Dehat, Raebareli, Fatehpur, Baghpat, Ghaziabad, Kushinagar, Maharajganj, Saharanpur, Sant Ravidas Nagar, Sultanpur, Unnao and Jalaun. Among these districts, Pratpgarh and Kanpur nagar districts were least performing with -19.36% and -13.51% growth rate in area and yield, respectively. Further, positive growth in area and negative growth in yield was observed in Kaushambi, Allahabad, Chitrakoot, Aligarh, Chandauli, Banda and Hamirpur. Remaining districts witnessed positive growth in yield and negative growth in area. It was observed that majority of the district formed a part of Q2 in this category. Majority of the districts showed negative growth in area, but this get compensated by increase in production and productivity up to some extent. The low yield of pulses in UP may be due to their cultivation by marginal and small farmers under rainfed conditions, coupled with inadequate crop management practices as observed by Ansari *et al.* (2022) in their study. Similarly Kumari and Malik (2023) observed a negative growth rate in pulse crops due to the reduction in the area allocated for pulses.

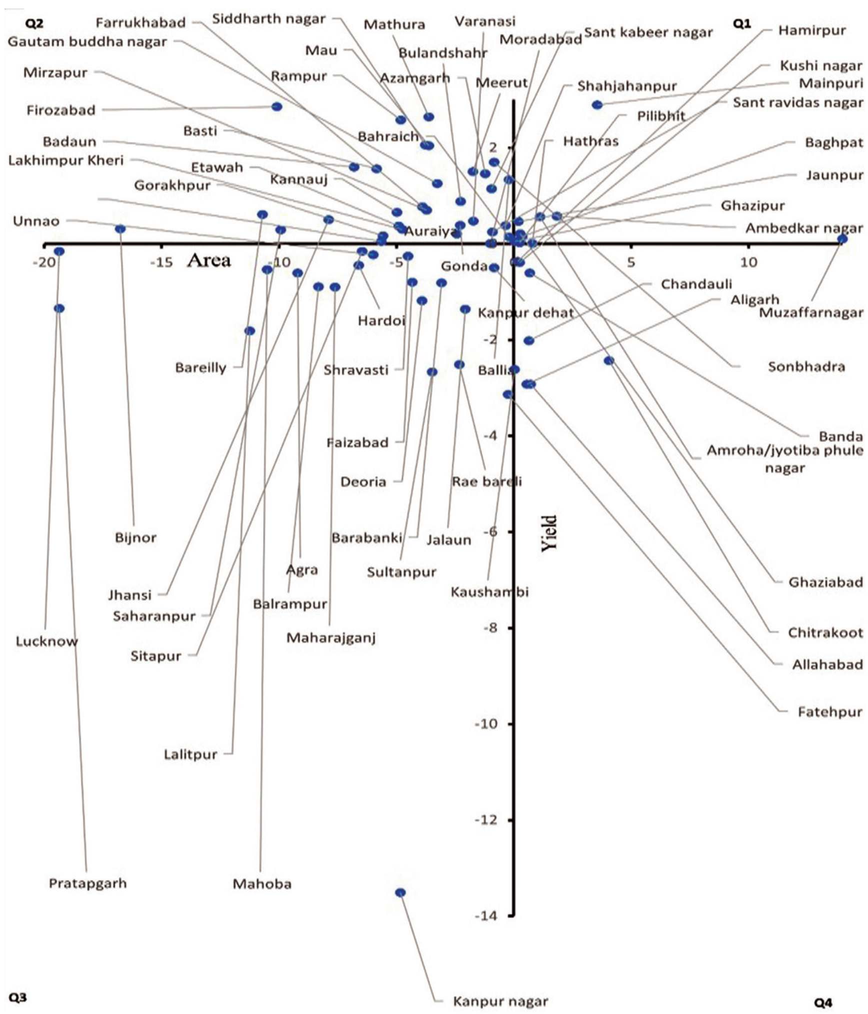

Fig. 3 Districtwise % growth rate of area and yield of pigeonpea in UP state (1997–2023).

Agro-climatic zonewise growth performance of pigeonpea: After observing the districtwise growth rates, further analysis was carried out on different agro-climatic zones of UP. The growth rate in area, production and yield of pigeonpea in nine agro-climatic zone was calculated for two periods viz. the pre-NFSM period (1997–2007) and the post-NFSM period (after 2007) to observe the effect of NFSM on pigeonpea. From Supplementary Table 1, it is clear that in the sub-period I (1997–2007), an increase in growth in area under pigeonpea was seen in Western Plain zone (II) and Bundelkhand zone (VI). Similar growth was spotted by Sah *et al.* (2021) in the Bundelkhand region which contributes 5.17% of the total pulse production. Western Plain zone (II) registered increased growth rate in both area (4.42%) and production (11.43%). On the contrary, most of the remaining agroclimatic zones witnessed an upward trend in area and a downward trend in production. The trend reflected decrease in pigeon pea yield across all zones except for zones I, II, and VII during sub-period I (1997–2007). In similar line, production also witnessed a decline in growth across all agroclimatic zones, except zones II, III, and VII, during the same period. In sub-period II (2007–2023), positive growth rate in area, production and yield of pigeonpea was observed for North Eastern Plain zone (VII), Eastern Plain zone (VIII) and Vindhyan Zone (IX). However, the CAGR in production showed a positive growth rate in majority of the zones. These phenomena are attributed to increase in incentives and input support in post NFSM period. Although all six agro-climatic zones (zone I to zone VI) recorded a decline in the growth rate of area under pigeonpea cultivation, most zones exhibited an increase in production and yield during the post-NFSM period (i.e. after 2007) in UP. However, certain zones showed negative growth in both area and production.

In zone I (Bhabar and Tarai zone), the area declined due to a shift toward commercial crops such as sugarcane and vegetables, though yield improved with better irrigation and short-duration varieties (Roy and Malviya 2016). Zone II (Western Plain zone) recorded moderate yield growth owing to NFSM interventions and adoption of improved varieties, despite reduced area from urban expansion (Sharma and Sisodia 2018). In zone III (Mid-Western Plain zone), yield gains were linked to better soil and pest management, though drought limited the area expansion (Hasan and Khan 2018). Zone IV (South-Western Semi-Arid zone) experienced decline in both area and production due to low profitability and poor market access. In zone V (Central Plain zone), yield increased slightly with improved seeds and demonstrations, but waterlogging and competition from short-duration pulses restricted area. Zone VI (Bundelkhand zone) showed negative growth in both area and production because of rainfed conditions, low input use, and weak market infrastructure in post NFSM period. Similar observations were noted by Rahman and Bee (2019) and Nagarethinam and Anjugam (2020).

Districtwise growth performance of pigeonpea in Bundelkhand and Vindhyan zone: Since Bundelkhand zone and Vindhya zone were found to be best performing ACZs in terms of highest yield growth rate in post NFSM period, a further district-level growth rate analysis was carried out for these regions (Supplementary Table 2). The data revealed that Banda, Chitrakoot and Hamirpur districts witnessed positive growth rate with respect to area under pigeonpea cultivation for sub-period 1 (1997–2007), sub-period 2 (2007–2023) and overall period (1997–2023), while Hamirpur, Jalaun, Mahoba, Mirzapur and Sonbhadra showed positive growth rate in yield during sub-period 1. However, all the districts of zone VI and IX witnessed positive growth rate in yield in sub-period 2. Four districts such as Banda, Jhansi, Mirzapur, and Sonbhadra, exhibited a positive growth rate in yield over the entire period (1997–2023).

During sub-period 2 (2017–2023), all the ACZs of UP state witnessed positive growth rate in pigeonpea yield which may be attributed to promotion of pulses by different agencies in terms of improved seeds, capacity building and other interventions made by different pulse promoting schemes. It may be due to inclusion of all the districts of UP state under NFSM in post 2016, which resulting to an increase in productivity in specific regions.

From the analysis of growth pattern of area, production and yield of pigeonpea in different agro-climatic zones of UP state under two different sub-periods, it could be inferred that efforts should be directed towards districts having high area but low yield for technological interventions and districts with low area but high yield for extension intervention.

The study concluded that the majority of the districts of Uttar Pradesh such as Hamirpur, Kushi nagar, Jaunpur, Banda, Chitrakooot, Jalaun, Jhansi and Mirzapur showed positive growth rates in yield during the post NFSM (2007–2023) period which may be attributed to the interventions (like demonstrations, need based inputs, trainings, etc.) under NFSM-pulses. The agro-climatic zonewise analysis showed that the Vindhyan, Central Western Plain and Bundelkhand zones have greater potential for future improvement, as these regions recorded relatively higher growth rates in production and yield compared with other zones. The districts of the Vindhyan and Bundelkhand regions exhibited high yield growth rates despite limited area expansion under pigeonpea. This indicates strong potential for targeted policy support and technological interventions. Area expansion under pigeon pea can be promoted as intercropping with urd/mung and fallow *kharif* cultivation, particularly in the Bundelkhand region. These measures can substantially enhance overall production of pigeon pea, stabilise pulse prices, and strengthen nutritional security in the country.

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