



REVIEW ARTICLE

Rajasthan's pulse sector: A data-driven analysis of varieties (2007–24) and production trends (2022–24)

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Abstract

This report presents a data-driven analysis of Rajasthan's pulse crop scenario and enumerates the characteristics of varieties, with a focus on production patterns from 2022 to 2024 and varietal development over a longer time span from 2007 to 2024. Using secondary data collected from various government publications, research institutions and agricultural databases, the study examines the variety, release and field acceptance of significant pulse crops, including chickpea, lentil, mungbean, urdbean and pigeonpea. The study emphasises the adoption and release of various cultivars in connection to local conditions, as well as their resistance to drought, pests and diseases. To identify new trends and changes in cropping patterns, the research also analyses recent production figures to examine changes in cultivated area, yield levels and overall output during the kharif and rabi seasons. The results address limitations including soil conditions, farmer choice and climate unpredictability and provide insights on how better varieties might boost yield. This study's observations are intended to help academics, extension organisations and policymakers promote resource-efficient and regionally appropriate cultivars. In Rajasthan, strengthening pulse production is especially crucial since it contributes nutritional protein for a predominantly vegetarian population and improves soil fertility through nitrogen fixation. Ultimately, our research supports on-going initiatives to strengthen the resilience of Rajasthan's pulse-growing regions, advance sustainable agriculture and increase food security.

Keywords: agricultural sustainability; area and production trends; kharif and rabi pulses; varietal adoption; yield performance

Introduction

Pulses are a major source of plant-based protein in India, especially for vegetarians (1, 2). In terms of production and consumption, they are complementary to cereals (2). The state of Rajasthan is one of the main producers of this essential crop, contributing significantly to the country's pulse output (3). Pulses require less water than cereals, increase soil fertility Through symbiotic Nitrogen production and help manage diseases and pests when they are rotated with grains (4). Numerous pulse crops, such as chickpeas, lentils, mungbean, urdbean and pigeonpea, are grown in its varied agroclimatic zones throughout both the rabi and kharif seasons (5).

The state of Rajasthan has made considerable efforts in the introduction of improved pulse varieties over the last two decades (6). The cultivars were developed to enhance production potential and resistance to disease, as well as to address local agro-ecological issues such as dryness, saline soil and insect infestations. Meanwhile, production patterns have been influenced by government support, weather conditions and market parameters (7). Despite the availability of extensive secondary data on pulse crops in Rajasthan, existing studies remain largely fragmented. There is a clear lack of comprehensive; data-driven analysis integrating long-term varietal development with recent production trends, efficiency and implications for agricultural planning and food security. This creates a gap in understanding the relationship between improved varieties and actual productivity outcomes.

While prior reports (e.g., DES annual summaries) provide descriptive pulse statistics, they lack integration of long-term varietal evolution (2007–24) with recent productivity trends (2022–24), statistical trend decomposition and Rajasthan-specific kharif-rabi comparison. This study fills this gap through descriptive analytics, normalized performance indexing and contextual interpretation of secondary data, offering actionable insights for varietal adoption amid climate variability-unlike fragmented national overviews. Our contribution lies in linking varietal traits to observed yield gaps, enabling targeted policy for Rajasthan's semi-arid zones. This study analyses the pulse economy of Rajasthan using a data-driven approach. It assesses the trends in the change of area, production and yield of major pulse crops during 2022–24. Secondly, it assesses the change and dispersion of pulse crop varieties during 2007–24 in Rajasthan. The present review combines information from government portals (Annual reports) and research institutions to understand several aspects relative to varietal diversity, yield. However, the findings are interpreted within the constraints of data variability and availability.

Materials and Methods

In this study, a descriptive and data-driven analytical review has been used to trace the growth, adoption and performance of major pulse crops in Rajasthan. The study analysed the release and

distribution of pulse varieties from 2007 to 2024 and trends in area, production and yield from 2022 to 2024. The present study was based purely on secondary data collected from official and research-oriented sources, such as the Directorate of Economics and Statistics (DES), Ministry of Agriculture and Farmers Welfare, Government of India; the Directorate of Agriculture, Government of Rajasthan; the concerned Indian Council of Agricultural Research (ICAR) institutions, IIPR and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT); and All India Coordinated Research Projects (AICRP) annual reports. Additional supporting data were obtained from AGMARKNET market databases and peer-reviewed scientific literature indexed in Scopus, Web of Science and Google Scholar. For each pulse crop, including chickpea, lentil, mungbean, urdbean and pigeonpea, important information was put together, such as the variety name, the year it was released, the best place to grow it, the average yield potential (q/ha), its ability to handle significant biotic and abiotic challenges and state-level area and production values. Variety performance and adoption patterns were summarised using descriptive statistics and seasonal trends in Kharif and Rabi pulses as well as variations in production levels over time were assessed using comparative graphical analysis. Under current agro-climatic circumstances, trend interpretation highlights changes in cropping patterns, varietal performance and seasonal yield responsiveness.

Scores were assigned based on a synthesis of secondary data. A normalised performance index (1 for very low up to 5 for very high) based on yield stability patterns, disease tolerance reports, drought resilience behaviour and relative adoption data recorded in AICRP on Pulses multi-location evaluation reports was used to score traits for radar chart visualisation (7) (Fig. 4). A normalised 1–5 scoring scale was used to assess the performance of different varieties and crops across a number of qualitative attributes. The scale represented 1- very low, 2- low, 3- moderate, 4- high and 5- very high levels of performance (6). Trait score assignment was based on yield stability patterns, disease incidence records [particularly Fusarium wilt and Yellow mosaic virus (YMV)], drought tolerance characteristics and farmer adoption extent as reported in AICRP on Pulses trial data, Krishi Vigyan Kendra (KVK) technical bulletins and State Agricultural Department Statistics. The compiled scores were organised in tabular form and plotted using the radar chart function in Microsoft Excel 2010. For each crop, the normalised values were plotted along the corresponding axes and connected to form a closed polygon. Distinct colors were used for each crop and a legend was included for identification. Each axis of the radar chart represents a specific attribute, allowing simultaneous visualisation of multiple performance parameters and enabling comparative analysis of strengths and limitations among major pulse crops under Rajasthan's agro-climatic conditions. Due to the heterogeneity of crops across seasons, statistical comparison using inferential tests was limited and the analysis primarily focuses on descriptive and comparative trends.

Importance of pulses in Rajasthan, India

The production of drought-tolerant pulses is encouraged by Rajasthan's semi-arid environment, which is characterised by low

rainfall (6). Pulses are a crucial crop for farmers since they can be consumed or sold, which contributes to economic stability and security of food for households (8). Due to their low water requirements and good drainage, pulses thrive in Rajasthan's sandy and loamy soils (9). When pulses are rotated consecutively, they fix nitrogen in the soil, which benefits other crops (10). A significant portion of Rajasthan's arable land is used for pulse cultivation. The main districts in Rajasthan that produce pulses are Bikaner, Jodhpur and Barmer (1). Most pulses are rainfed; however during times of lower rainfall in Rajasthan, more effective micro-irrigation techniques like drip irrigation are becoming increasingly popular (11). The state has also used drought-resistant, high-yielding seed types to increase potential harvests. Throughout Rajasthan's agricultural history, pulses have been a staple crop (12).

Rajasthan contribution in area and production of pulses

In the agricultural year 2022–23, the Kharif season accounted for an area of 39.51 lakh hectares, contributing 29 % to the total sown area, while its production stood at 17.25 lakh tonnes, contributing 21 % to the total agricultural output. In contrast, the rabi season covered a smaller area of 21.19 lakh hectares, representing 14 % of the total area, but yielded a higher production of 23.11 lakh tonnes, also contributing 14 % to total production shown in (Table 1). This indicates that while kharif crops occupied a larger share of cultivated land, rabi crops were significantly more productive, generating more output from a smaller area.

Status of pulses: Rajasthan

As shown in Table 2, in year 2022–23, chickpea (*Cicer arietinum* L.), a major rabi pulse crop, contributed 21 % of the total area under pulses and accounted for 19 % of total pulse production, with a yield of 1081 kg per hectare (kg/ha). Lentil (*Lens culinaris* Medik.), also a rabi crop, had a relatively smaller area share of just 1 %, yet contributed 2 % to the overall production due to a higher yield of 1313 kg/ha.

Among the pulses, mungbean (*Vigna radiata* (L.) R.Wilczek) dominated with 66 % area contribution (of which 48 % pertains to Kharif specifically) and 68 % of production (40 % Kharif-specific), though its yield was relatively low at 419 kg/ha. Urdbean (*Vigna mungo* (L.) Hepper), another kharif pulse, occupied 13 % of the pulse-growing area (11 % under kharif) and contributed 11 % to production (7 % Kharif), with a yield of 394 kg/ha. Data for pigeonpea (*Cajanus cajan* (L.) Huth) in 2022–23 was not provided. In the following year, 2023–24, chickpea continued to be a key rabi crop, covering 1775.37 thousand hectares and producing 1919.17 thousand tonnes, maintaining its yield at 1081 kg/ha. Lentil saw an increase in both area and yield, with 27.35 thousand hectares under cultivation, resulting in 34.30 thousand tonnes of production and a yield of 1254 kg/ha. Mungbean, under the kharif season, was grown on 2564.02 thousand hectares and produced 813.22 thousand tonnes, though its yield decreased to 344 kg/ha. Data for urdbean and pigeonpea for 2023–24 remains unavailable. As for the year 2024–25 varieties, no data has been reported yet.

Table 1. The contribution of Rajasthan in terms of area and production of pulses

Season	Year	Area (lakh ha)	Percentage (%) contribution	Production (lakh tonnes)	Percentage (%) contribution
Kharif	2022–23	39.51	29	17.25	21
Rabi	2022–23	21.19	14	23.11	14

(Source: DES, Ministry of Agri. & FW (DA&FW), GoI.) (13).

Table 2. Status of pulses: Rajasthan (2022–24)

Pulses	Season	Area contributed (2022–23; values in %)	Production contributed	Yield (Kg/ha)
Chickpea (<i>Cicer arietinum</i>)	Rabi	21	19	1081
Lentil (<i>Lens culinaris</i>)	Rabi	1	2	1313
Mungbean (<i>Vigna radiata</i>)	Kharif	66 (48)	68 (40)	419
Urdbean (<i>Vigna mungo</i>)	Kharif	13 (11)	11(7)	394
Pigeonpea (<i>Cajanus cajan</i>)	Kharif	NA	NA	NA
(2023–24 ; values in thousand ha/tonnes)				
Chickpea (<i>Cicer arietinum</i>)	Rabi	1775.37 (40.65)	1919.17 (69.34)	1081
Lentil (<i>Lens culinaris</i>)	Rabi	27.35 (0.03)	34.30 (0.03)	1254
Mungbean (<i>Vigna radiata</i>)	Kharif	2564.02 (58.73)	813.22 (29.40)	344
Urdbean (<i>Vigna mungo</i>)	Kharif	NA	NA	NA
Pigeonpea (<i>Cajanus cajan</i>)	Kharif	NA	NA	NA

(Source: DES, Ministry of Agri. & FW (DA&FW), Gol.(13–16); NA - Data not available).

Chickpea: A number of improved chickpea varieties have been developed and adopted in Rajasthan to accommodate the agro-climatic conditions of the state shown in (Table 3). Among them, Aparna (RSG 991), released in 2007, yields 16–17 q/ha and is moderately resistant to dry root rot, wilt, collar rot and pod borer, with added drought tolerance. Arpan (RSG 896) and Aruna (RSG 902), also released in 2007, offer yields of 14–15 and 20–21 q/ha respectively and show moderate resistance to dry root rot, wilt, pod borer and nematodes. Gauri (GNGK 1499) and Sangam (GNG 1488), each yielding 18–19 q/ha, are tolerant to major diseases like root rot, wilt and stunt, with Sangam showing resistance to *Helicoverpa* (pod borer). Anshul (RSG 959), suitable for frost-prone areas, yields 15–16 q/ha and is resistant to wilt and dry root rot. Ganguar (GNG 1581) is a variety adopted over parts of Rajasthan, which yields 24–25 q/ha and is resistant to wilt, Ascochyta blight, stunt and root rot. High-yielding varieties like GNG 1958 (Marudhar) (26–27 q/ha) and Kota Desi Chana-1 (RKG 13-515) (24–25 q/ha), both released in recent years, are popular in the state for their resistance to wilt, root rot and pod borer. Newer introductions such as Pusa Parvati (BG 3062), Jawahar Gram 24 (JG 24) and Phule Vikram (Phule G 08108), adopted partly in Rajasthan; also offer good yield potential and disease resistance. Varieties like Keshav (GNG-2261) and Kota Kabuli Chana-1 (RKGK 13-271) further cater to Rajasthan's needs with specific traits like pod borer tolerance, yellowish seed colour and resistance to multiple soil-borne diseases. RSG 888, CSJ 515, RSG-973 (Abha), CSJD-884 (Akash), RSG-991, RSG 963, CSJK 174, CSJK 21 are the varieties of chickpea (Anonymous. 2022–23).

Lentil: Several types of lentil varieties have been released and adopted over the years to meet the agro-climatic challenges, like drought, high temperatures and soil-borne diseases, in the state of Rajasthan. As stated in (Table 4), one of the earlier varieties, IPL 406 (2007), was adopted in the NWPZ, including Rajasthan, offering moderate yield (12–14 q/ha) with resistance to rust and wilt. Introduction of Pant Lentil 8 (2010) and IPL 316 (2013) strengthened for the state, combining higher yields (up to 16 q/ha) with moderate resistance to rust, wilt and pod borer. One of the major local varieties

developed was RLG 5 (2016), a double-podded variety specifically recommended for Rajasthan and showing moderate resistance to root knot nematodes, a problem in sandy soils. Apart from this, the state benefited from the release of different varieties of Kota Masoor.

The state has been benefited by Kota Masoor 1 (RKL 607-1) and Kota Masoor 2 (RKL 14-20) varieties released in 2018, the suit Rajasthan with tolerance to wilt, drought and high temperatures with yields of 12–15 q/ha. Kota Masoor 3 (RKL 605-03) and Kota Masoor 4 (RKL 58 F 3715) were released in the year 2020 and 2021. These combine abiotic stress tolerance with acceptable levels of yield, 12–14 q/ha and rust resistance. More recent developments like RVL 13-5 and RVL 13-7 released in 2019 and L 4729 in 2020 provides further increases in yield, up to 18 q/ha, together with better resistance to wilt and improved seed traits, adding to the suitability of growing lentils in the region. The newest release, LL 1613 (2023), is recommended for Rajasthan and other NWPZ states. It has a high yield potential of 16–17 q/ha, though detailed resistance traits are yet to be published. Lentil breeding efforts in Rajasthan focused on tackling the big challenges farmers face: lack of water, high temperatures and diseases in the soil. By creating and releasing lentil varieties specifically suited to the region, they've made a real difference in keeping lentil farming productive and sustainable in Rajasthan.

Mungbean: Rajasthan is a major beneficiary of mungbean varietal development, targeting regional issues such as yellow mosaic virus, drought and soil-borne pests. As shown in Table 5, the earliest variety, MH 2-15 (Sattya; 2008), yields 10–13 q/ha and has been adopted in the NWPZ /CZ regions including Delhi, Haryana, Rajasthan and western Uttar Pradesh. It provides resistance to mungbean yellow mosaic virus (MYMV) and *Cercospora* leaf spot (CLS). Likewise, IPM 02-3, which has been released in 2009, is a big-seeded variety, resistant to MYMV and relatively tolerant to major pests, with a yield potential of 11–12 q/ha. It has been adopted in Rajasthan and other northern states. In 2014, MH 421 was released for NWPZ/CZ (including Rajasthan), offering MYMV resistance and a yield of 10–12 q/ha.

Table 3. Chickpea varieties (Gram/Chana)

Variety	Year of release	Yield (q/ha)	Area of adoption	Characteristics
Aparna (RSG 991)	2007	16–17	RJ	Moderate resistance to pod borer, stunt, collar rot, wilt and dry root rot. Drought-tolerant.
Arpan (RSG 896)	2007	14–15	RJ	Resistance to wilt and dry root rot that is moderate. Both nematodes and pod borer. Nematodes and pod borer moderate resistance.
Aruna (RSG 902)	2007	20–21	RJ	Pod borer, nematodes and dry root rot and wilt moderate resistance.
Gauri (GNGK 1499)	2007	18–19	RJ	Tolerant to stunting, wilting and dry root rot. Pod bore tolerable.
Sangam (GNG 1488)	2007	18–19	RJ	Resistant to stunting and root rot. (Pod Borer) resistant to <i>Helicoverpa</i> .
Rajas (Phule-G9425-9)	2007	18–20	NWPZ (RJ, PN, UK, DL, HR) CZ MH, NHZ (J&K)	Fusarium wilt resistant.
Anshul (RSG 959)	2008	15–16	RJ	Prone to frost and has demonstrated resistance to DRR and wilt.
Ganguar (GNG 1581)	2008	24–25	NWPZ (HR, PN, UP) CZ (RJ), NHZ (J&K)	Resistant to root rot, stunting and wilt Ascochyta blight.
Raj Vijay Gram 203 (RVG 203) JSC 56	2013	19–20	CZ (MP, MH, GJ) NWPZ (UP, RJ)	It is moderately resistant to dry root rot and wilt.
GNG 1958 (Marudhar)	2013	26–27	NWPZ (HR, PN, RJ, UP, UK, DL)	Wilt-resistant.
GNG – 1969 (Triveni- Kabuli)	2013	22–23	NWPZ (HR, PN, RJ, UP, UK, DL)	It has 26.2 g/100 seeds and a creamy beige seed colour.
GLK 28127	2013	21–22	NWPZ (HR, PN, RJ, UP, UK)	Wilt-resistant cultivar.
Vallabh Kabuli Chana-1 (WCGK 2000-16)	2015	23–24	NWPZ, RJ,DL,PN,UP, UK, HR, NHZ (J&K)	Fusarium wilt resistance is moderate.
RVG 202 (JSC 55)	2015	20–21	CZ (MP, CG, GJ, MH) NWPZ (RJ,UP)	Moderately resistant to collar rot, dry root rot and wilt.
Pusa 3022 (BG 3022)	2015	18–19	NWPZ (HR, PN, RJ, UP, UK, DL)	Resistance to Fusarium wilt is moderate.
Bidisha (BG 1084) WBG 29	2015	23–24	NWPZ (HR,PN, RJ, UP, DL) NHZ (J&K)	Moderately resistant to fusarium wilt.
Teej (GNG 2144)	2016	22–23	NWPZ (HR, PN, RJ, UP, UK, DL)	Tolerances to Fusarium wilt disease.
Aman (CSJ 515)	2016	24–25	NWPZ (HR, PN, RJ, UP, UK, DL) NHZ (HP)	Tolerant of Ascochyta blight and BGM and resistant to dry root rot, wilt and collar rot.
Meera (GNG-2171)	2017	20–21	NWPZ (HR, PN, UK, DL, RJ.UP) NHZ (HP, J&K)	Tolerant to Fusarium wilt disease
Pant Gram 5 (PG0109)	2017	22–23	NWPZ (PN, RJ, UP, UK, DL, HR) NHZ (J&K)	Tolerant to Fusarium wilt disease.
Phule Vikrant (Phule G0405)	2018	20–21	CZ (GJ, MP, MH, S.RJ) NEPZ (WB)	Moderately resistant to Fusarium wilt.
IPC 2006-77	2019	20–21	CZ (CG, MP, GJ, S.Raj. BK-UP)	Moderately resistant to wilt, dry root rot and stunt.

Haryana Chana No 7 (HC 7) (H 12-55)	2019	24–25	NWPZ (PN, HR, W- UP, Delhi, N-Raj., J&K HP, UK)	Tolerant to <i>Helicoverpa armigera</i> .
Kota Desi Chana-1 (RKG 13-515)	2020	24–25	RJ	Tolerant of major disease (root rot, wilt). Pod borer-tolerant.
Kota Kabuli Chana-1 (RKGK 13-271)	2020	24–25	RJ	Moderately resistant to wilt, collar rot, dry root rot, botrytis grey mould, Ascochyta blight and stunting. Able to withstand pod borer.
Pusa Parvati (BG3062)	2020	21–22	CZ (MH, MP, BK- UP, S.RJ)	Highly resistant to stunt, dry root rot and wilt.
Phule vikram (Phule G 08108)	2020	22–23	CZ (MH, MP, GJ), NWPZ(UP, RJ)	Fusarium wilt-resistant and appropriate for mechanical harvesting.
Jawahar Gram 24(JG 24) (JG 2016-24)	2020	22–23	CZ(MP, MH, CG, GJ, RJ, BK- UP)	Resistant to fusarium wilt.
IPCK 2013-163 (Madhav)	2021		NWPZ (NWPZ) PN, HR, N-RJ, DL, W-UP	It has creamy beige seeds that are big (28.7 g/100 seed weight) and resistant to wilt disease. (https://iipr.icar.gov.in/new-varieties/)
Keshav (GNG-2261)	2021	20–21	RJ	Yellowish brown seed colour.
Jawahar Gram Kabuli 6 (JGK 6) (JGK 201732)	2021	4–18	NWPZ (HR, J&K, PN, RJ, UP)	Shattering resistance and lodging tolerance. Planting rate: 100–120 kg/ha.
Kota Kabuli Chana-2 (RKGK 13499)	2021	17–18	NWPZ (HR, J&K, PN, RJ, UK, DL)	Wilt, dry root rot and collar rot are all avoided and stunt disease is somewhat avoided.
Raj Vijay Kabuli Gram 2020 (RVSSG 63)	2021	20–23	NWPZ (HR, PN, RJ, UK)	Resistance to stunt is moderate. In storage, resistant to pulse beetle and pod borer (<i>Helicoverpa</i>).
Raj Vijay Gram 204 (RVG 204) (RVSSG 8102)	2021	20–21	CZ (MP, CG, RJ, GJ, MH)	Able to withstand wilt. Harvesting by machine is feasible (Desi type variety).
Kota kabuli Chana- 2(RKGK13-499)	2021	17–18	NWPZ (HR, PN, UK, DL, RJ.UP)	Mildly resistant to stunt disease and resistant to wilt, collar rot and dry root rot.
Nandyal Gram 810 (NBeG 810)	2021	15–18	NWPZ(PN, HR, W & BK-UP, DL, N-RJ, UK) CZ(GJ, MH, W- MP) NHZ(J&K)	Moderately resistant to wilt.
Gujarat Kabuli Gram (GJGK 1617)	2021	13–14	NWPZ(PN, HR, N- RJ & UK)	Moderately resistant to wilt.
Pusa Chickpea 4005	2021	15–16	NWPZ (HR, PN, RJ.W-UP)	Tolerant to drought.
Kota kabuli Chana-3 (RKGK 13-414)	2021	17–18	CZ(MP, MH, GJ) RJ &UP	Resistant to wilt.
L 558 (GLK 17301)	2023	6–7	NWPZ (HR, PN, RJ, UK)	Beige colour owl head shaped large bold seeds.
Pusa JG 16 (BGM 10221 DTIL)	2023	13–14	CZ(CG, GJ); RJ,UP	Resistant to fusarium wilt.

Source: - Anonymous. 2022-23- i) Project Coordinator's Report, Annual Group Meet on Chickpea – Aug. 2019, AICRP, ICAR, IIPR, Kanpur ii) ICAR annual report 2022–23 iii) www.seednet.gov.in . iv) DPD, Gol, Bhopal (MP), (13–16). NWPZ: North Western Plains Zone; NEPZ: North Eastern Plains Zone; CZ: Central Zone; PZ: Peninsular Zone; NHZ: Northern Hills Zone; RJ: Rajasthan; PN: Punjab; UK: Uttarakhand; DL: Delhi; HR: Haryana; UP: Uttar Pradesh; MP: Madhya Pradesh; GJ: Gujarat; MH: Maharashtra; CG: Chhattisgarh; WB: West Bengal; HP: Himachal Pradesh; and J&K: Jammu and Kashmir.

Table 4. Masoor lentil varieties

Variety	Year of release	Yield (q/ha)	Area of adoption	Characteristics
IPL 406	2007	12–14	NWPZ (HR, PN, RJ, UP, UK)	Resistant to rust and wilt.
Pant Lentil 8 (Pant L 063)	2010	15–16	NWPZ (HR, PN, UP, UK, DL, RJ) CZ (GJ)	Moderately resistant to wilting and rust. Pod borer-resistant.
IPL 316	2013	14–15	NEPZ (BH, JH) CZ (CG, GJ, MP,	Tolerance to wilt and rust.
RLG 5 (Keshwanand Masoor 1)	2016	15–16	RJ	Moderately resistant to root knot nematode and double-podded.
RVL 11-6	2017	11–12	CZ (CG, MP, GJ, MH) NWPZ (RJ, UP)	Wilt tolerant.
L 4717 (Pusa Ageti Masur)	2017	12–13	CZ (MP, CG) NWPZ (UP, RJ) NEPZ- WB	Ascochyta blight and wilt resistance.
Kota Masoor 1 (RKL 607-1)	2018	13–14	RJ	Tolerant to wilt.
Kota Masoor 2 (RKL 14-20)	2018	12–15	CZ (CG, MP, MH) RJ	Tolerant to heat and drought.
L 4727	2018	11–15	CZ/NWPZ (CG, MP, MH /RJ)	Moderately resistant to wilt.
Kota Masoor-1 (RKL 607-1)	2018	10–14	CZ (CG, GJ, MP, MH) NWPZ (UP, RJ)	Resistant to both high temperatures and drought.
RVL 13-5 (Raj Vijay Lentil 13-5)	2019	12–14	CZ/NWPZ (CG,MP,MH/RJ)	Resistant response to wilt. Strong seeds and high yield.
RVL 13-7 (Raj Vijay Lentil 13-7)	2019	14–15	CZ/NWPZ (CG, MP/ RJ)	Resistant response to wilt. Strong seeds and high yield.
L 4729	2020	17–18	CZ/NWPZ (CG, MP/ RJ,UP)	Low prevalence of the main pests. The resistance to wilt is moderate.
Kota Masoor 3 (RKL 605-03)	2020	12–14	NWPZ (RJ, PN, UP) CZ (MP, CG, GJ, MH), SZ (OD)	Resistant to both high temperatures and drought.
LL 1373	2020	15–16	NWPZ (UP, N-RJ, PN,HR, UK)	Rust and wilt resistance is moderate.

(Source: Anonymous. 2022-23- DPD, Gol, Bhopal (M.P)), (13–16). NWPZ: North Western Plains Zone; NEPZ: North Eastern Plains Zone; CZ: Central Zone; SZ: Southern Zone; RJ: Rajasthan; PN: Punjab; UK: Uttarakhand; DL: Delhi; HR: Haryana; UP: Uttar Pradesh; MP: Madhya Pradesh; GJ: Gujarat; MH: Maharashtra; CG: Chhattisgarh; WB: West Bengal; BH: Bihar; JH: Jharkhand; OD: Odisha; and N-RJ: North Rajasthan.

Table 5. Varieties of mungbean (Green gram)

Variety	Year of release	Yield (q/ha)	Area of adoption	Characteristics
MH 2-15 (Sattya)	2008	10–13	NWPZ/CZ (DL, HR, RJ, W. UP)	CLS and MYMV-resistant.
IPM 02-3	2009	11–12	NWPZ (DL, HR, HP, J&K, PN, RJ)	Big seeds, MYMV resistance and a relative tolerance for major pests.
MH 421	2014	10–12	NWPZ/CZ (DL, HR, RJ, W.UP)	Resistant to MYMV.
IPM 410-3 (Shikha)	2016	11–12	NWPZ/CZ (RJ, PN, HR, DL, HP, UK, J&K, MP, MH & GJ)	Resistant to MYMV
IPM 205-7 (Virat)	2016	13–15	KA, TN, MP, GJ , RJ, MH, UP	Highly resistant to YMD, PM and CLS.
RMG 975(Keshwanad Mung 1)	2016	8–9	RJ	Both root knot nematode and MYMV tolerance are moderate.
MSJ 118 (Keshwanand Mung 2)	2016	7–8	RJ	Moderately tolerant to MYMV.
MH 1142	2020	11–12	NEPZ & NWPZ (BH, HA, DL, JH, PB, RJ, UP, UK, WB, AS)	Resistance to MYMV and moderate resistance to anthracnose and powdery mildew.

(Source: [DPD, Gol, Bhopal (M.P), (13),(14),(15),(16). NWPZ: North Western Plains Zone; CZ: Central Zone; NEPZ: North Eastern Plains Zone; RJ: Rajasthan; PN/PB: Punjab; HR/HA: Haryana; DL: Delhi; HP: Himachal Pradesh; UK: Uttarakhand; J&K: Jammu & Kashmir; UP: Uttar Pradesh; W.UP: Western Uttar Pradesh; MP: Madhya Pradesh; MH: Maharashtra; GJ: Gujarat; BH: Bihar; JH: Jharkhand; WB: West Bengal; AS: Assam; TN: Tamil Nadu; and KA: Karnataka.

The year 2016 saw the release of several varieties with regional focus and enhanced resistance profiles. IPM 410-3 (Shikha) is resistant to MYMV and widely adopted in multiple states including Rajasthan. IPM 205-7 (Virat), though suited for southern and central India, including Rajasthan, showed higher yields (13-15 q/ha) and high resistance to yellow mosaic disease (YMD), powdery mildew and CLS. For Rajasthan-specific development, RMG 975 and MSJ 118 were released the same year. Both are moderately tolerant to mungbean yellow mosaic virus (MYMV), with RMG 975 also showing tolerance to root knot nematodes important for managing pest-infested soils in arid regions. Their yield potentials are 8-9 q/ha and 7-8 q/ha respectively. The more recent variety MH 1142, released in 2020, is recommended for NEPZ and NWPZ states including Rajasthan. It resists MYMV along with moderate resistance to anthracnose and powdery mildew, with a yield range of 11–12 q/ha. In addition to these specific releases, a series of RMG varieties developed at ARS Durgapura-RMG 62, RMG 268, RMG 344, RMG 492 and RMG 975-have shown moderate tolerance to drought and web blight, making them particularly suited to Rajasthan's semi-arid conditions.

Urdbean: Rajasthan has witnessed many developments in urdbean (black gram) varieties over the years, shown in Table 6. Mainly due to MYMV and other regional diseases and pests, varieties have been developed in urdbean. Another such variety is Pant Urd 31. Released in 2008, this variety has a yield potential of 10–12 q/ha. It can be cultivated in several regions, including CZ, which covers Rajasthan. The variety is resistant to MYMV. Next is Vishwas (NUL-7). Released in 2012, this variety performs well in Rajasthan and other neighboring states. The variety was resistant to powdery mildew, along with MYMV. An interesting variety is Mukundra Urd-2 (KPU 405). Released in 2018, this variety is exclusively developed for NWPZ, including Rajasthan. Its characteristic features include a yield of 10–11 q ha⁻¹. It is strongly resistant to MYMV. One such variety is PDU 1 (Basant Bahar). Released in 2019, this variety is extensively used for cultivation in both NWPZ and CZ. Its considerable features include a higher yield (13–14 q/ha), with resistance to MYMV. Additionally, for adapting to local climatic conditions, another variety is necessary.

Hence Kota Urd 3(KPU 524-65) variety was developed. Released in 2020, this variety is exclusively developed for adapting to climatic demands in Rajasthan. The variety offers moderate resistance to MYMV, leaf spot and anthracnose, which can decrease overall growth in arid regions. The most recent variety developed in 2021 was Pant Urd 12. It has a high yield potential of 14–15 q/ha and is cultivated in Rajasthan along with many northern states. This variety possesses resistance to MYMV, web blight, leaf crinkle and curl viruses, root rot and several insect pests like whitefly, pod-borer, maruca and pod-fly; thus, highly suitable for integrated pest and disease management in the diversified agro-ecologies of Rajasthan.

Pigeonpea: Rajasthan, prominent in Central Zone (CZ) and parts of the North Western Plains Zone (NWPZ), benefits from pigeonpea varieties developed for disease resistance, climatic adaptation and higher yields. Early varieties such as TT 401, Pusa 2002 and IC-550413, with yields ranging between 15–19 q/ha, with modest maturity (Early to Mid-Early), indeterminate growth habit and resistance to fusarium wilt, suitable for semi-arid climatic conditions prevalent in Rajasthan, were developed in 2007. During this time, Jawahar Tur JKM 189, having a 32 q/ha potential, stood out as a high-yielding variety with a high degree of resistance to Fusarium wilt and moderate resistance to sterility mosaic disease (SMD) and Phytophthora blight. Next, varieties with resistance to pests and diseases followed. TJT 501, with resistance to pod borers and pod fly, both important pests in these regions, appeared in 2009. PA 291, with resistance to Phytophthora stem blight, SMD and yields ranging between 16–18 q/ha, suitable for NWPZ regions including Rajasthan and IPA 203, with resistance to same above-mentioned diseases, yields ranging between 16–18 q/ha, suitable for same zones, followed in 2008 and 2014, respectively. Next, varieties with moderate to highest resistance to Fusarium wilt, SMD and Pod borers, with yields ranging between 18–20 q ha⁻¹, suitable for CZ regions including Rajasthan, such as Rajeshwari (2012) and PKV Tara (2013), followed. Most recently, Bheema GRG-152 (2020) and Pant Arhar 6 (PA 421), with moderate resistance to Wilt and SMD, with m2 yields between 12-20 q/ha, suitable for CZ and NWPZ regions in Rajasthan, appeared. Next is IPA 15-6, developed in 2021, which

Table 6. Varieties of urdbean (Black gram)

Variety	Year of release	Yield (quintals/hectare)	Area of adoption	Characteristics
Pant Urd 31	2008	10–12	CZ (RJ, CG); SZ (AP, OD); NEPZ (UP, BR); NHZ (TR, UK)	Resistant to MYMV
Vishwas (NUL-7)	2012	11–12	CZ(CG, GJ, MP, MH, Part of RJ, BK-UP)	Resistant to MYMV and powdery mildew.
Mukundra Urd-2 (KPU 405)	2018	10–11	NWPZ (RJ, HR, PN, Plains of HP, UK.)	Resistant to MYMV.
PDU 1 (Basant Bahar)	2019	13–14	NWPZ (RJ, HR, PN, Plains of HP, UK) CZ (CG, GJ, MP, MH, Part of RJ,BK-UP)	Tolerant to MYMV.
KPU 524-65 (Kota Urd 3)	2020	10–12	RJ	Moderately resistant to MYMV, leaf spot and anthracnose.
Pant Urd 12	2021	14–15	NWPZ (HR, PN, UP, UK,RJ) NHZ (J&K)	Resistant against MYMV, web blight, leaf crinkle, leaf curl Virus and root-rot diseases, white- fly, pod-borer, pod bug, maruca and pod-fly.

[Source: DPD, Gol, Bhopal (M.P), (13–16)]. NWPZ: North Western Plains Zone; CZ: Central Zone; SZ: Southern Zone; NEPZ: North Eastern Plains Zone; NHZ: Northern Hills Zone; RJ: Rajasthan; CG: Chhattisgarh; GJ: Gujarat; MP: Madhya Pradesh; MH: Maharashtra; AP: Andhra Pradesh; OD: Odisha; UP: Uttar Pradesh; BR: Bihar; TR: Tripura; UK: Uttarakhand; HR: Haryana; PN: Punjab; HP: Himachal Pradesh; BK-UP: Bundelkhand Uttar Pradesh; and J&K: Jammu and Kashmir.

showed progress toward higher yields (19 q/ha) with highest resistance to Fusarium wilt and SMD, considered one of the prominent threats to pigeonpea cultivation. Most recently is Renuka (BDN 2013-2)', developed in 2023, which showed resistance to SMD and moderate resistance to Wilt, with steady yields ranging between 18–21 q/ha for CZ regions including Rajasthan. Overall, pigeonpea varietal development for Rajasthan (Table 7) has focused on early maturity, high yield potential and durable resistance to key diseases and pests, making these varieties highly suitable for sustainable Tur cultivation under the state's variable and often harsh agro-climatic conditions.

Results and Discussion

Seasonal area distribution

The kharif season recorded a larger sown area (39.51 lakh ha) compared to rabi (21.19 lakh ha) shown in Table 1 and Fig. 1. This suggests that kharif pulses dominate Rajasthan's crop-planning in terms of land allocation, despite Rabi's higher productivity per hectare (previous data: 23.11 vs. 17.25 lakh tonnes).

Production Comparison

Despite having less sown area, rabi pulses produced a higher output (23.11 lakh tonnes) compared to kharif (17.25 lakh tonnes) as shown in Table 2 and Fig. 2. (17). This indicates that greater yield stability in rabi crops like chickpea and lentil. Higher vulnerability of kharif pulses (mungbean, urdbean) to rainfall fluctuations and pest incidence (Table 8) (14–18). Chickpea and lentil drive stable productivity, while mungbean and urdbean suffer climatic risk, requiring improved seed systems and irrigation support (19).

Seasonal yield performance

The seasonal comparison of average yields shows a significant advantage for rabi pulses (Chickpea and Lentil) (average yield $\approx$ 1200 kg/ha) are comparatively more stable and productive than kharif pulses (average yield $\approx$ 400 kg/ha) under Rajasthan conditions shown in (Fig. 3.). Higher productivity in chickpea and lentil is associated with irrigation availability, cooler temperatures and relatively lower pest incidence. Kharif gaps arise from rainfed marginal lands and erratic monsoons, unlike national rabi grains (+ 4.2 %/year post-2000). Implications: Promote drip irrigation and policy for heat-tolerant kharif lines to close 25 % state-national yield gaps; agronomically, rotate with cereals for N-fixation (20).

This indicates, Rabi pulses are more stable and productive. Kharif pulses suffer from rainfall dependency, pest pressure (particularly YMV) and heat stress. Mungbean occupies the largest proportion of pulse cultivation area in Rajasthan during Kharif but contributes lower yield, whereas chickpea, though covering less area, contributes higher total production, making it the major contributor to pulse production in the state. Kharif (mungbean/urdbean) yields suffer rain dependency (39.51 lakh ha but 17.25 lakh tonnes), YMV, heat; rabi (chickpea/lentil) benefits irrigation, stability (21.19 lakh ha, 23.11 lakh tonnes).

Trend in total pulse area and production (2022–24)

Rajasthan's pulse area declined from 60.70 lakh ha (2022–23) to 43.66 lakh ha (2023–24), with production dropping from 40.36 to 27.66 lakh tonnes (21). This is a decrease of about 28 %. The total amount of pulses produced also went down, from 40.36 lakh tonnes to 27.66 lakh tonnes, which is a reduction of around 31 %. This decrease is due to decreased monsoon rainfall in desert areas (22).

Table 7. Varieties of pigeonpea

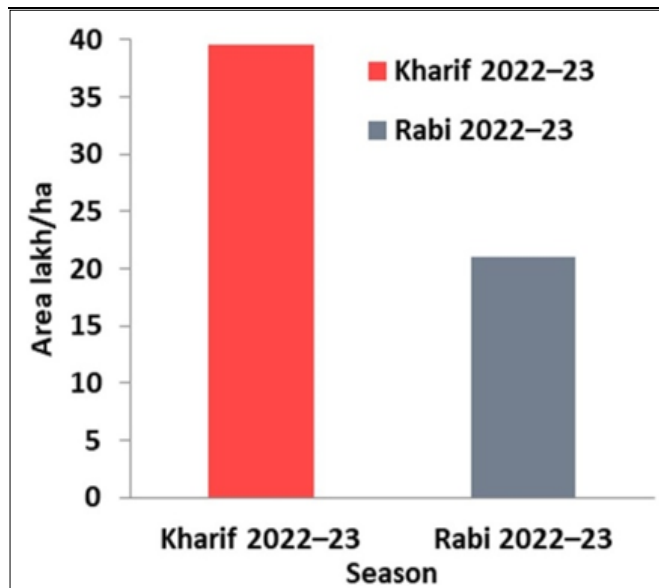
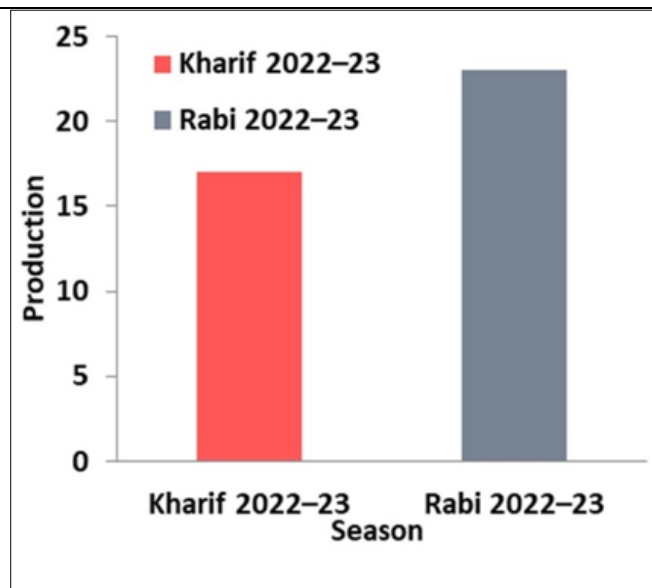
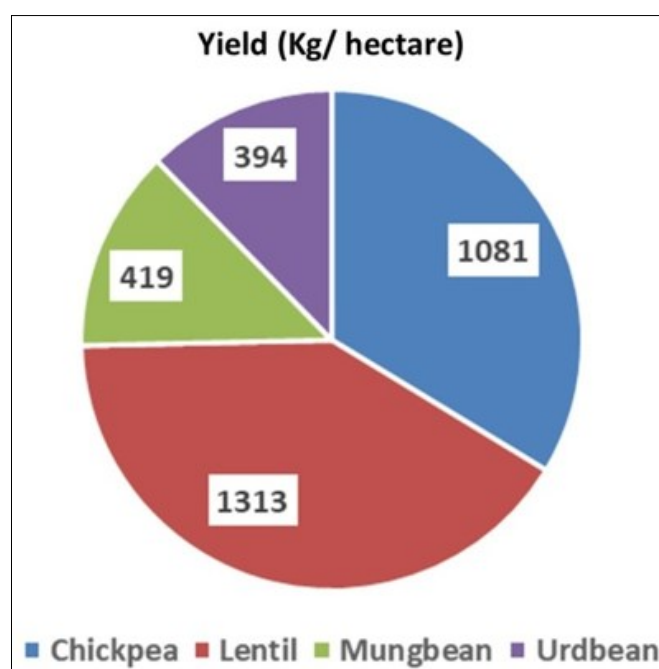
Variety	Year of release	Yield (q/ha)	Area of adoption	Characteristics
TT 401	2007	15–16	CZ (CG, MP, MH, RJ, GJ) NWPZ (DL, HR, JH, PN, RJ, UK)	Indeterminate, mid-early maturing, semi-spreading, early maturing and wilt-resistant.
Jawahar Tur JKM-189	2007	19–32	CZ (CG, MP, MH, RJ, GJ)	Moderately resistant to Phytophthora blight and sterility mosaic at medium and high disease levels and resistant to fusarium wilt.
Pusa 2002	2007	16–17	CZ (CG, MP, MH, RJ, GJ)	Semi-spreading, early maturing, indeterminate and appropriate for the pigeonpea-wheat cropping scheme.
IC-550413	2007	18–19	CZ (CG, MP, MH, RJ, GJ)	Modified tolerance to <i>Helicoverpa armigera</i> and pod borer and resistance to fusarium wilt and sterility mosaic virus.
TJT 501	2009	18–19	CZ (CG, MP, MH, RJ, GJ)	Pod Borer and Pod Fly Tolerable.
PA 291	2008	16–18	NWPZ (PN, HR, DL, RJ, West UP, Plains of UK)	Tolerant to Phytophthora stem blight and pod borer.
Rajeshwari (Phule T 0012)	2012	18–20	CZ (CG, MP, MH, RJ, GJ)	Tolerable to pod borer and pod fly and somewhat resistant to SMD and fusarium wilt
PKV, Tara (TAT-9629)	2013	19–20	CZ (CG, MP, MH, RJ, GJ)	Semi-spreading, indeterminate and resistant to pod fly and pod borer.
IPA 203	2014	16–18	NWPZ (PN, HR, DL, RJ, W-UP, Plains of UK)	Tolerable to fusarium wilt and phytophthora blight and resistant to sterility mosaic disease.
Bheema GRG-152	2020	12–14	CZ (CG, MP, MH, RJ, GJ)	Resistant to SMD and Wilt diseases to a moderate extent.
Pant Arhar 6 (PA 421)	2020	17–20	NWPZ (DL, HR, JH, PN, RJ, UP, UK)	Resistant to SMD and Wilt diseases to a moderate extent.
IPA 15-6	2021	19	CZ (MP, RJ, GJ, MH and CG)	It is resistant to fusarium wilt and SMD. (https://iipr.icar.gov.in/new-varieties/)
Renuka (BDN 2013-2)	2023	18–21	CZ (MP, MH, GJ, RJ)	Both sterility mosaic disease and wilt resistance are moderate.

(Source: DPD, Gol, Bhopal (M.P); <http://www.dpd.gov.in>) (13–16).

CZ: Central Zone; NWPZ: North Western Plains Zone; CG: Chhattisgarh; MP: Madhya Pradesh; MH: Maharashtra; RJ: Rajasthan; GJ: Gujarat; DL: Delhi; HR: Haryana; JH: Jharkhand; PN: Punjab; UP: Uttar Pradesh; UK: Uttarakhand; W-UP/West UP: Western Uttar Pradesh; and Plains of UK: Plains of Uttarakhand.

Table 8. Impact of season on crop area and output

Season	Area	Output	Interpretation
Kharif	High	Low	Yield affected by rainfall and disease stress
Rabi	Low	High	Better productivity and varietal performance

**Fig. 1.** Comparison of total pulse area under kharif and rabi seasons in Rajasthan.**Fig. 2.** Variation in total pulse production between kharif and rabi seasons in Rajasthan.**Fig. 3.** Average yield levels of major pulse crops in Rajasthan.

In certain regions, the incidence of yellow mosaic virus (YMV) in urdbean and mungbean crops encourages diversification toward cash crops or short-duration crops (23). When comparing the productivity of different types of pulses, it was found that rabi pulses were more stable in terms of yield than kharif pulses. In fact, the productivity of major rabi pulses was about three times higher than that of Kharif pulses, with a yield of around 1200 kg per hectare compared to 400 kg per hectare for Kharif pulses. This is likely due to the fact that rabi pulses are grown in cooler and more irrigated conditions.

Varietal performance across major pulse crops

Varietal development shows steady improvement in terms of disease resistance, adaptation to climatic conditions and overall yields for Rajasthan's major pulses. Early varieties for chickpeas such as RSG 991, RSG 896 and GNG 1488 have been developed for areas with sufficient moisture. Progress made in varieties GNG 1958 and RVG 202 can be attributed to improved levels in terms of yields, irrespective of wilt and root rot infection. Due to lower winter temperatures, the states recommended lentil cultivars demonstrated modest yield stability under Rabi conditions. Due to its vulnerability to Yellow Mosaic Virus and moisture stress, mungbean and urdbean showed greater area coverage but relatively lower productivity in kharif pulses.

Nevertheless, more recent varieties with better YMV tolerance and short-duration growth habits are already being adopted. Because to the lower winter temperatures, the states recommended lentil cultivars demonstrated modest yield stability under Rabi conditions. Due to its vulnerability to YMV and moisture stress, mungbean and urdbean showed greater area coverage but relatively lower productivity in kharif pulses. Nevertheless, more recent varieties with better YMV tolerance and short-duration growth has are already being adopted.

The radar (Fig. 4.) shows notable variations in the performance of pulse crops. Chickpeas and lentils exhibit comparatively greater yield stability under Rabi conditions, but mungbean and urdbean exhibit poorer stability due to their susceptibility to Yellow Mosaic Virus and the erratic rains during Kharif.

The drought tolerance is good but acceptance is limited due to prolonged growing season and irrigation access. These variables bring to attention how crucial it is to encourage pulse patterns that are region specific and stress tolerant.

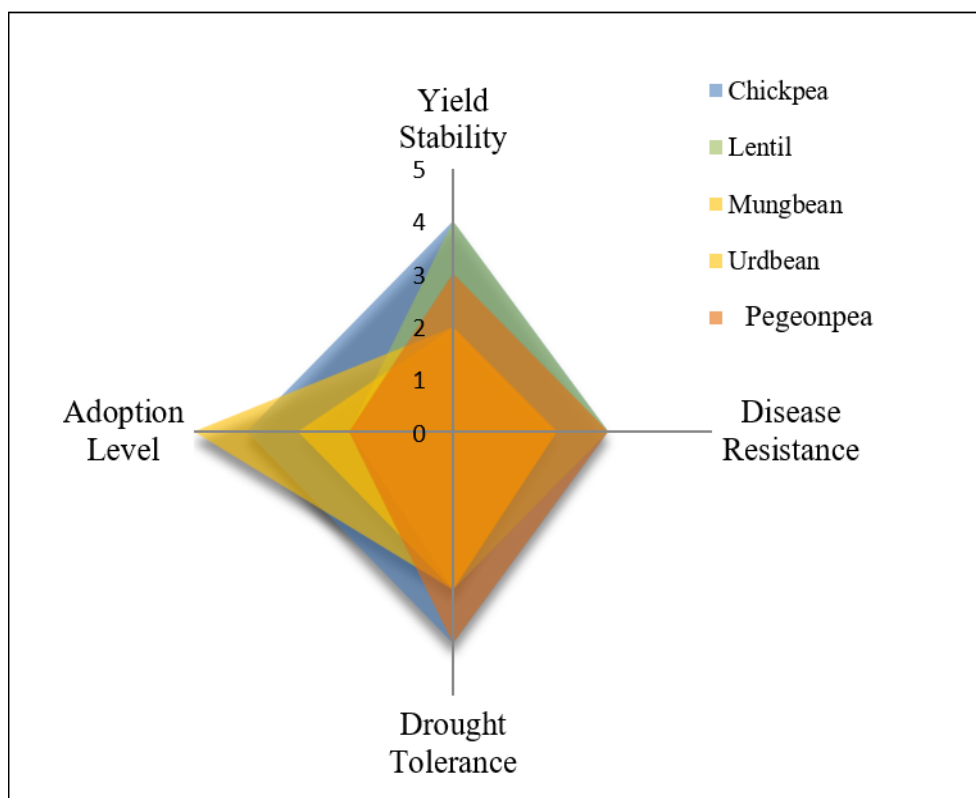


Fig. 4. Comparative radar chart illustrating relative yield stability, disease resistance, drought tolerance and adoption levels for major pulse crops cultivated in Rajasthan. (Scale: 1: very low, 2: low, 3: moderate, 4: high and 5: very high levels of performance).

Implications for climate, farming and policy

Pulse cultivation area declined substantially during the study period (from 60.70 lakh ha (22, 23) to 43.66 lakh ha next) due to climatic variability and production constraints. Kharif mungbean yield went 419 to 344 kg/ha. The decline was primarily associated with weak monsoon conditions (down 15–20 %), higher evaporation (+ 14.8 %), YMV in humid heat. Rabi crops such as chickpea (1081 kg/ha) and lentil (1313 kg/ha) demonstrated comparatively greater yield stability, primarily due to cooler temperatures and relatively lower disease incidence (24, 25).

Irrigation key: Irrigation availability remains a major constraint in Rajasthan, where irrigated pulse area is substantially lower than the national average. GNG 1958 could do 26–27 q/ha with better seeds. Rotate on 39.51 lakh Kharif ha for +10–15 % cereals, fix salt. Adoption of drip irrigation systems has shown potential to improve mungbean productivity by approximately 25–30 % under water-limited conditions.

Rajasthan contributes 10–14 % of India's total pulse production but receives a smaller share of funding. Minikits RMG 975 are designated for Bikaner-Jodhpur. Subsidies, such as RKL 607-1, aim to address the 25–30 % gap. Farmer Producer Organizations (FPOs) may support value-chain development and market access for high-performing pulse varieties like the premium GNG 1581. Further AICRP should be linked to breeding efforts similar to those in the state of Madhya Pradesh (25).

Limitations

The data utilised in this study were derived from secondary sources, such as DES/ICAR reports. While these sources present limitations in terms of consistency and the absence of field verification, they nonetheless offer valuable insights into the development of pulse crops in Rajasthan. Future research should focus on conducting empirical trials, employing ARIMA models for yield forecasting and

incorporating farmer feedback to inform more effective policy-making.

Conclusion

This review provides a comprehensive overview of pulse varietal development and production trends in Rajasthan during 2007–24. The findings revealed clear seasonal differences in pulse productivity across the state. While kharif pulses covered a larger cultivation area, Rabi pulses performed better in terms of yield, with chickpea and lentil recording productivity levels of 1081 kg/ha and 1313 kg/ha, respectively. Their relatively better performance can be attributed to favourable winter conditions, lower disease pressure and improved irrigation availability.

The analysis further showed a considerable decline in pulse cultivation and production between 2022–23 and 2023–24, with total cultivated area decreasing by nearly 28 % and overall production declining by about 31 %. These changes reflect the increasing influence of climatic variability, particularly erratic rainfall, moisture stress and disease incidence in Kharif pulses such as mungbean and urdbean.

To boost the production of pulses in Rajasthan, it's crucial to develop better varieties that can withstand the semi-arid conditions. These new varieties should have higher yields, be more resistant to diseases and adapt easily to the local environment. But that's not all - improving irrigation systems, making good quality seeds more accessible and promoting crops that can handle climate change will also be vital. Additionally, providing more support to farmers through extension services will play a significant role in increasing pulse productivity and ensuring a sustainable future for pulse production in the state. By taking these steps, Rajasthan can improve its pulse production, which will have a positive impact on the environment, the economy and the people who depend on these crops.

Since the study is based mainly on secondary data sources, the findings should be interpreted within the limitations of available datasets and absence of field-level validation. Future research should therefore focus on field-based assessments, spatial analysis and predictive approaches to support more effective pulse production planning under changing climatic conditions.

Future prospective

Future research must prioritise comprehensive datasets for robust statistical analysis of pulse performance. There is a clear need for crop-specific as well as region-specific studies that can more accurately capture how different varietal traits influence productivity under diverse agro-climatic conditions. At the same time, bringing in field-level data and farmer-centred studies can offer much deeper insights into real-world adoption patterns and the reasons behind existing yield gaps. Such approaches help bridge the gap between experimental outcomes and on-ground realities. Looking ahead, research can also benefit from the use of advanced analytical tools and modelling techniques, which can strengthen evidence-based planning and policymaking for Rajasthan's pulse sector. Together, these efforts can support more informed decisions and contribute to sustainable improvements in productivity and resilience.

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Authors' contributions

CR compiled and analysed the secondary data, developed the varietal comparison framework and drafted the manuscript. DC conceived the review, supervised the analysis, contributed to interpretation of results and critically revised the final manuscript. Both authors read and approved the final manuscript.

Compliance with ethical standards

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