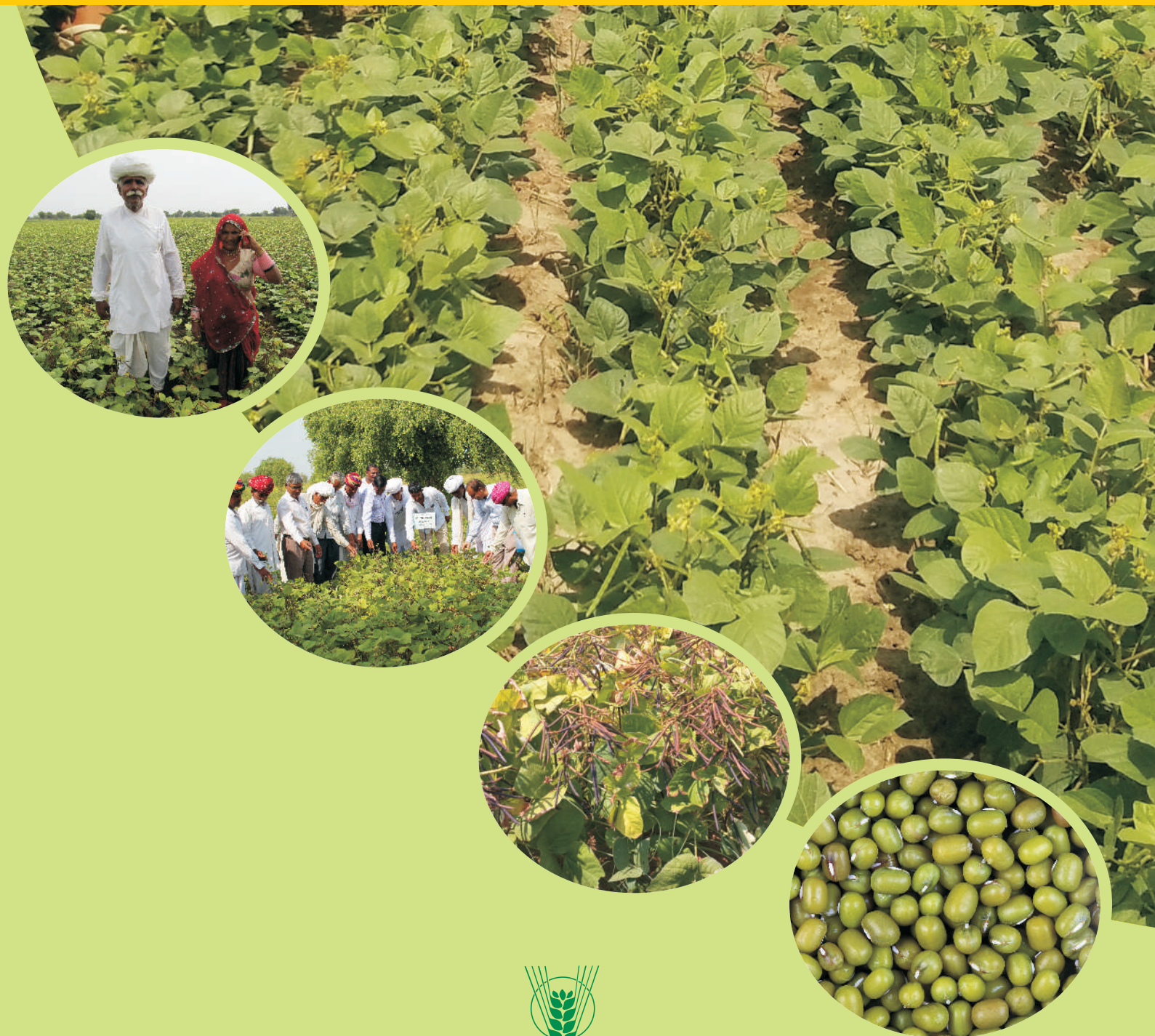


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POTENTIAL OF GREENGRAM IN RAJASTHAN

INSIGHTS FROM CLUSTER FRONTLINE DEMONSTRATIONS

MS Meena | JP Mishra | HN Meena | Dilip Panwar



ICAR-Agricultural Technology Application Research Institute

Zone-II, Jodhpur-342 005, Rajasthan, India



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ICAR-Agricultural Technology Application Research Institute, Zone-II
भाकृअनुप-कृषि प्रौद्योगिकी अनुप्रयोग अनुसंधान संस्थान, क्षेत्र-II

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कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली 110 001

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FOREWORD

India is the largest producer and consumer of pulses globally with 36.11 million hectare area and 27.66 million tons of production which constitute 36.63% and 27.44% of production. As per FAOSTAT 2022, the annual consumption of pulses is 30.07 million tons, against the domestic supply of 27.66 million tons. Hence, country has imported 2.41 million tons to meet out the consumption requirement. About 20% of the total area under food grains is accounted for pulses with about 7-10% of the production in the country. The annual import of pulses was 24 million tons in 2022-23 which increased sharply in 2023-24 due to augmentation of consumption demand. This import surge amounted to USD 3.75 billion.

Enhancing pulse production is a national priority. Recognizing the significance of pulses in dietary intake and protein nutrition the Government of India implemented National Food Security Mission in 2007 aiming at enhancing pulses production. The Cluster Frontline Demonstrations (CFLDs) on Pulses is one of the major technology interventions under the National Food Security Mission for infusion of new technology of pulses and reducing the yield gap between potential yield and realized yield at farmers' fields. The CFLDs are implemented under ICAR-KVKs system since 2015-16. The demonstrations on major pulse crops such as pigeonpea, greengram, blackgram, mothbean, chickpea, and lentil are conducted throughout the country including Rajasthan, Haryana, and Delhi. The ICAR-ATARI, Zone-II, Jodhpur has been coordinating these CFLDs in these three states.

Under CFLDs, the participating farmers are provided with quality seeds and proven technological packages including critical inputs for production and protection of crops. Over the years the CFLDs on pulses have exhibited significant results for reducing yield gaps in all major pulse crops. Greengram is the major pulse crop of Rajasthan accounting 2.33 million hectare area and 1.17 million tons of production. The CFLDs on greengram in Rajasthan and Haryana have yielded much-awaited breakthrough in varietal deployment for better production. To our best satisfaction, some alternatives of summer greengram are also emerging in better rainfall districts of Rajasthan.

It is a matter of great pleasure to learn that ICAR-ATARI, Zone-II, Jodhpur has brought out this important publication Potential of Greengram in Rajasthan: Insights from CFLDs. I wish to compliment the authors of this publication and hope that it will be an important resource for researchers, extension and development personnel, students, policy makers, farmers and all other stakeholders.

Date: 9th July, 2024

Place: New Delhi


(Himanshu Pathak)

डॉ. ऊधम सिंह गौतम

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MESSAGE

Pulses have been an integral part and parcel of cropping system in India since time immemorial. The intrinsic capacity of pulses to assimilate atmospheric nitrogen makes them unique for restoring soil fertility and environmental sustainability. Considering their immense benefit, the Food and Agriculture Organization (FAO) observed 2016 as the International Year of Pulses. India is the largest producer of pulses globally. The nutritional benefits of pulses as a major source of plant protein to majority of vegetarians in India make them very important constituent of our daily diets. As a consequence, we are the world's largest consumer also. The production of pulses though increased substantially, yet short of consumption demand leading to sizeable imports. In spite of quantum jump in production and consequent availability of pulses, the per capita availability is still low as compared to the recommended dietary intake of 52g/capita/day.

About 87% of the pulses cultivation in India is under rainfed condition. At farm level, pulses are still grown on marginal and low fertility soils with suboptimal management and inputs application. This is one of the major reasons for low productivity of pulses. In the past, planned and concerted research led to development of more than 775 high yielding varieties with biotic and abiotic stress resistance and tolerance. To take these varieties and improved production technologies at a faster delivery mode, a strong component of technology deployment through frontline demonstrations on pulses was included in National Food Security Mission (NFSM). The dedicated efforts of all stakeholders under NFSM accomplished the highest ever production of pulses of 27.66 million tons during 2022-23. The country moved towards self-sufficiency of pulses during 2014 to 2024 due to development and deployment of improved technologies, innovative seed system and positive price signals through MSP.

The frontline extension played a pivotal role in recent revolution of pulses production in the country. The innovative cluster frontline approach implemented since 2015-16 at farmers' field by KVKs proved an effective tool in re-energizing the production systems. The CFLDs attracted the farmers and extension personnel not only understanding the improved technologies but also in fine tuning the package of practices for early adoption by them. This has helped in deploying HYVs in diversified agri-food systems with resilience to weather aberrations.

I am pleased to learn that ICAR-ATARI, Zone-II, Jodhpur has documented the significant work "Potential of Greengram in Rajasthan: Insights from CFLDs," based on experiences from various agro-climatic zones of the state. I congratulate the authors for their efforts and hope that this publication will serve as a valuable resource for all stakeholders involved in pulse research and development.

Date: 10th August, 2024

Place: New Delhi

(Udham Singh Gautam)

Dr. J.P. Mishra

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PREFACE

Agriculture and allied sectors contribute 18.2% of the country's GDP. Beyond the economic indicators, the social indicators are more important. The sector absorbs about 45.9% of the workforce of country, albeit with low income per person per unit time. Indian agriculture system is a mosaic of crops, livestock, fisheries, agroforestry, and other rural on-farm and off-farm activities. The cropping enjoyed centrality due to its constituents of staple food, nutrition, and income. The value of output from cropping is still 40-45% of the total agricultural value of output. Pulses have been the important segment of cropping in India historically for their twin benefits. Firstly, they provide much-needed protein nutrition to our majority vegetarian population, and secondly adding to soil health and fertility even with very low input application. The food grain production has reached to the highest ever with 332.29 million tons during 2023-24. The record production of over 24.24 million tons of pulses in 2023-24 is an outstanding achievement. Amongst the various states that contributed to pulses production, Rajasthan holds the prime portion with 17.07% share. Greengram, mothbean, and pigeonpea during monsoon and chickpea during winter season are the major pulse crops of Rajasthan. The greengram is the prime pulse crop of Rajasthan. Pulses are important for the health and nutrition of people and the sustainability of soil and environment. They are water-efficient crops and grow well in the areas where other water-loving crops cannot be grown successfully. Once included in the cropping system, pulses add to resilience against climatic stresses.

The publication, “Potential of greengram in Rajasthan: Insights from Cluster Frontline Demonstrations” is an attempt of in-depth insights into some key learnings of the collaborative project of Indian Council of Agricultural Research (ICAR) and Department of Agriculture & Farmer Welfare (DAFW) implemented by ICAR-Agricultural Technology Application Research Institute (ICAR-ATARIs), Zone-II, Jodhpur since 2015-16. The project created an enabling ecosystem for the farmers and extension institutes during 2016-2022 that demonstrated the latest varieties and matching technologies leading to significant improvement in greengram productivity in Rajasthan. The yield of greengram increased by 21.5% to 37.6% over farmer's practices which reflects the minimum guaranteed yield a farmer can harvest if adopts the proven technology. The growth in areas and income of the farmers under quality seeds due to farmer-to-farmer extension of seed and technology has also been established under CFLDs. The challenges faced by farmers in greengram cultivation have also been synthesized alongwith actionable recommendations for augmenting the production and productivity of pulses in Rajasthan as a way forward.

I extend my gratitude to Dr. U.S. Gautam, Deputy Director General (Agricultural Extension), Assistant Director Generals, and all the colleagues of the Division of Agricultural Extension, ICAR headquarter, New Delhi for their constant support and guidance in implementing the project and documenting this publication. The financial support provided by DAFW and technical support in the implementation by Krishi Vigyan Kendras (KVKs) is highly appreciated and recognized. I am confident that this book shall be a useful resource for all the stakeholders of R&D in pulses crops. The feedback and suggestions for the improvement in the publication are always welcome.

Date: 9th September, 2024

Place: Jodhpur



(J.P. Mishra)

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ACRONYMS

ACZs	Agro Climatic Zones
ATARI	Agricultural Technology Application Research Institute
BAU	Business As Usual
BCR	Benefit Cost Ratio
CAGR	Compound Annual Growth Rate
CFLDs	Cluster Frontline Demonstrations
CVRC	Central Variety Release Committee
EC	Emulsifying Concentrate
e-NAM	E-National Agriculture Market
FAO	Food and Agriculture Organization
FFE	Farmer to Farmer Extension
FP	Farmers' Practice
FPC	Farmer Producer Company
FPO	Farmer Producer Organization
GOI	Government of India
GVA	Gross Value Added
HIG	High Income Growth
HYG	High Yield Growth
HYVs	High Yielding Varieties
ICAR	Indian Council of Agricultural Research
ICMR	Indian Council of Medical Research
IIPR	Indian Institute of Pulses Research
INM	Integrated Nutrient Management
KVK	Krishi Vigyan Kendra
MA&FW	Ministry of Agriculture and Farmers' Welfare
MSP	Minimum Support Price
MYMV	Mungbean Yellow Mosaic Virus
NAFED	National Agricultural Cooperative Marketing Federation
NDC	National Development Council
NFSM	National Food Security Mission
NITI	National Institution for Transforming India
PDS	Public Distribution System
PKVY	Paramparagat Krishi Vikas Yojana
PLA	Participatory Learning and Action
PMFBY	Pradhan Mantri Fasal Bima Yojana
PMKSY	Pradhan Mantri Krishi Sichayee Yojana
PRA	Participatory Rural Appraisal
SAUs	State Agricultural Universities
SHC	Soil Health Card
SHG	Self Help Group
SVRC	State Varieties Release Committee
TMOP	Technology Mission on Oilseed and Pulses
WPI	Wholesale Price Index



Executive Summary

Growth in pulses production during 2014 to 2024 has been a revolution. The efforts and role of all the stakeholders has contributed to it. In India, more than a dozen pulse crops are cultivated depending upon the suitability of soils, seasons and weather. Amongst the various pulses, vigna group of pulses are dominated by greengram (*Vigna radiata*) and blackgram (*Vigna mungo*). Due to shorter maturity period of 60-70 days of majority of the varieties of greengram, the crop enjoys characteristic feature of being climate resilient and stress adaptive pulse in India. It has a very widespread coverage in Rajasthan with more than 32% of the nation's production contributed by the state. However, the level of productivity is very low compared to some of the agricultural input and management agile states. The prime reason for low productivity is use of farm saved seeds of old varieties by the farmers. Development and deployment of high yielding varieties, technologies, toiling efforts of millions of farmers, timely delivery of associated inputs and services and the encouraging price signals at appropriate time given by the government boosted the production by almost 10 million tons in 2023-24 over the level of 2014-15. The frontline institutions KVKs have been spearheading one of the innovations in agricultural extension through cluster frontline demonstrations since 2016-17. The clusters approach has been an improvement over individual farmers' field demonstrations implemented under National Food Security Mission. The CFLDs proved effective in demonstrating new technologies through large group mobilization of farmers with more visible impacts. During 2016-2022, 10101 CFLDs on greengram were organized across 25 districts of Rajasthan under 9 agro-climatic zones of the state for popularization of improved technologies amongst farmers and farm women. The CFLDs established 30% yield advantage with improved package of practices and varieties as compared to farmer's practices and farm saved seeds. An additional income of about 2 USD per day (Rs.8,616 in 60 days at one ha) achieved by the farmers implemented CFLDs. The total CFLDs conducted on 4,277 ha added \$ 5.5 lakh (\$1 = Rs. 80) (Rs. 447 lakh) to the economy.

The irrigated and input intensive tracts falling in the Zone-Ib (Hanumangarh and Sriganganagar districts) of the state are very similar to irrigated tract of Haryana and Punjab demonstrated the highest productivity of 934 kg/ha of greengram. Next was Zone-V (Baran and Bundi districts) with the yield of 876 kg/ha. Various KVKs of the state together demonstrated 13 improved varieties of greengram. Among these, medium duration (65-70 days) 'RMG-492' emerged as the highest yielding with an average yield of 983 kg/ha. 'GM-4' and 'IPM-2-14' green gram with 849 kg/ha and 811 kg/ha yields followed RMG 492. The quality seeds produced through CFLDs covered 118767.8 ha translating into assimilation of atmospheric nitrogen in the soil to the tune of 4750712.2 kg, this saved input cost of urea (104515.6 q) of Rs. 5.61 crores, otherwise would have incurred for nitrogenous fertilizers. The CFLDs have been able to help deploying high yielding and climate resilient varieties and practices of greengram for diversified agri-food systems in the Rajasthan.



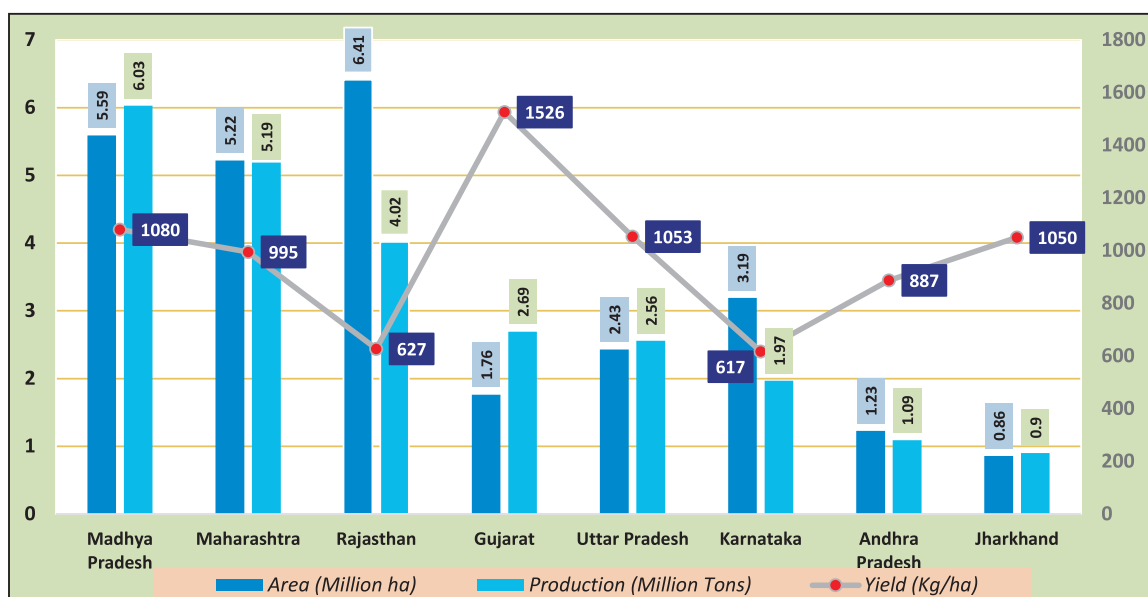
Another innovation in the offing is introduction of short-duration greengram 'IPM 02-03', 'Sikha' (IPM-410-3), 'Virat' (IPM-205-7) and 'MH-1142' during summer season in selected districts. It shall lead to enhanced cropping intensity to 300% in Sawai Madhopur, Kota, Banswara, Dungarpur, Pratapgarh, Baran, and parts of Sirohi districts in Rajasthan. The farmer-to-farmer horizontal expansion of improved greengram varieties 'MH-1142' and 'GM-7' is also practiced. The seed exchange extended up to distances of 225 km through relatives and progressive farmers and fostering broader adoption of superior varieties and associated agricultural practices. The capacity development of 47043 farmers and farm women through 529 training sessions and 823 extension activities was also effected by KVKs.

What is important and imperative is to enhance the seed replacement and varietal replacement of greengram. This is being addressed by facilitating KVKs under overarching mechanism of coordination and monitoring of ICAR-ATARI, Zone-II, Jodhpur for participatory seed production and collaborating with state departments and other agencies. Besides, HYVs of greengram such as RMG-492, GM-4, and IPM-2-14 are being promoted through farmer-to-farmer extension. Further, recent varieties are also being popularized. To expand the area under greengram, nich areas are being explored for the introduction of greengram. A coordinated and concerted effort of all stakeholders and institutions shall usher into a new era of pulses production in Rajasthan.



1. Introduction

Pulses are major dietary source of protein for the larger vegetarian population in India. These crops provide the quality plant protein to humans, improve fertility and physical structure of soil, and can be cultivated even under stress conditions with minimum use of applied inputs by virtue of their intensive capacity to assimilate atmospheric nitrogen. In India, Rajasthan holds first rank in pulses acreage (6.41 million ha) followed by Madhya Pradesh (5.59 million ha) and Maharashtra (5.22 million ha). In contrast, Madhya Pradesh is the top most pulses producing state with 6.03 million tons followed by Maharashtra (5.19 million tons) and Rajasthan (4.02 million tons) (Fig. 1).



Source: Ministry of Agriculture & Farmers' Welfare, GOI, 2022.

Fig. 1 Area, production and yield of pulses in major producing states in India (2022)

Pulses also play an important role in food, nutritional and environmental sustainability. Greengram (*Vigna radiata* L. Wilczek) is an important crop amongst group of pulses. The crop is very versatile and is grown in kharif, rabi and spring/summer seasons in different agro-climatic regions. It performs well as companion crops and also in sole stand. The crops of this groups are intercropped with sugarcane (*Saccharum officinarum*), maize (*Zea mays*), pearl millet (*Pennisetum glaucum*), cotton (*Gossypium herbaceum*), groundnut (*Arachis hypogea*), sorghum (*Sorghum bicolor*) and pigeonpea (*Cajanus cajan*) during kharif season. It is cultivated in sequence cropping, relay crop in rice fallows during rabi in peninsular regions and as catch crop between wheat and rice in irrigated conditions of north-western India during spring/summer seasons. Greengram is highly nutritious, containing approximately 24-28% protein, 1.0-1.5% fat, 3.5-4.5%



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fiber, 4.5-5.5% ash, and 59-65% carbohydrates on a dry weight basis (Tsou *et al.*, 1979), providing 334-344 kcal of energy (Srivastava and Ali, 2004) for a vast majority of the Indian population. When combined with cereals, they provide a balanced mix of essential amino acids with high biological value. Its unique ability to assimilate atmospheric nitrogen through root *Rhizobium* symbiosis provide adequate nitrogen for its own requirements and leave residual effect to succeeding crops as well (Ali, 1992). Pulses also significantly suppress weed growth (20-45%) when intercropped with tall cereals, thereby reducing weed control costs (Ali, 1988). Due to their short growth duration and insensitivity to photoperiod, greengram are considered a good crop for intensification and diversification.



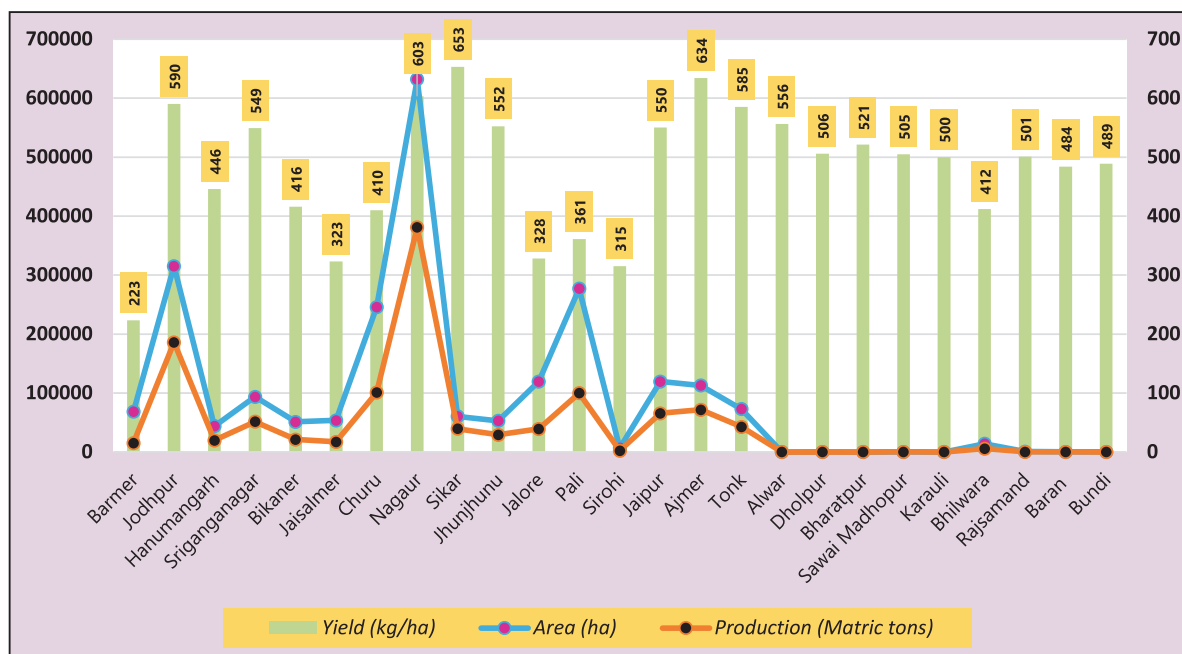
2. Greengram production scenario

It is believed that greengram is a native of India and Central Asia and grown in these regions since prehistoric times. It is widely cultivated throughout the Asia, including India, Pakistan, Bangladesh, Sri Lanka, Thailand, Laos, Cambodia, Vietnam, Indonesia, Malaysia and South China. Greengram best thrives in regions with an annual rainfall ranging from 60 to 75 cm and favours a hot and warm climate. It is known for its resilience, making it the hardiest among all pulse crops, showcasing exceptional tolerance to drought conditions. Consequently, it flourishes even in adverse environments, particularly in drought-prone areas during kharif season. The worldwide cultivated area of greengram spans approximately 7.3 million ha, with an average yield of 721 kg/ha (Bhajan *et al.*, 2021). India and Myanmar together contribute 30% of the global greengram output, which stands at 5.3 million tons. Other large producers are China, Indonesia, Thailand, Kenya, and Tanzania (Nair *et al.*, 2020).



Fig. 2 Soil sampling by KVK experts at farmer's field in Baran district

Greengram covered 5.54 million ha during 2022-23, yielding 3.67 million tons with a productivity of 663 kg/ha. Greengram alone contributes 10% to the overall pulse production and occupies 16% of the total pulses area. Rajasthan is a dominant contributor in terms of area (2.33 million ha) and production (1.17 million tons) with 42.05% and 32.07% share in area and production respectively. The other greengram producing states are Madhya Pradesh, Maharashtra, Karnataka, Odisha, Tamilnadu and Gujarat. Rajasthan state is endowed with diverse climates, which provides conducive conditions for greengram cultivation. During 2022-23, production of greengram in Rajasthan was 1.17 million tons from an area of 2.33 million ha with an average productivity of 504 kg/ha. The district-wise profile of greengram in Rajasthan is presented in Fig. 3. Nagaur, Jodhpur, and Pali are the major greengram districts of the state.



Source: Agricultural Statistics of Rajasthan (Various reports from 2014-15 to 2022-23).

Fig. 3 District wise area, production and yield of greengram in Rajasthan (2016-20)

Greengram cultivation spans all three seasons across the country. Notably, there is a gradual shift observed from kharif to summer cultivation, supported by assured irrigation. The agro-climatic zones of Rajasthan state, each with specific attributes, are presented in Table-1.

Table-1 Agro-climatic zones of Rajasthan with its specific attributes.

Zone		Districts	Total area (Mha)	Soil pattern	Major crops	Average rainfall (mm)	Temperature range (in °C)	Area (ha) under greengram (2020-21)
I _a	Arid Western Plain	Barmer and Jodhpur	4.74	Desert soils and sand dunes aeolian soil, coarse sand in texture some places calcareous	Kharif- Pearl millet, Mothbean, Sesame Rabi- Wheat, Mustard, Cumin	200-370	8.0-40.0	349375 (13.6)
I _b	Irrigated North Western Plain	Sriganganagar and Hanumangarh	2.10	Alluvial deposits calcareous, high soluble salts & exchangeable sodium	Kharif- Cotton, Cluster bean Rabi- Wheat, Mustard, Gram	100-350	4.7-42.0	271263 (10.6)
I _c	Hyper arid partial irrigated Western Plain	Bikaner, Jaisalmer and Churu	7.70	Desert soils and sand dunes aeolian soil, loamy coarse in texture & calcareous	Kharif- Pearl millet, Mothbean, Clusterbean Rabi- Wheat, Mustard, Gram	100-350	3.0-48.0	456386 (17.8)

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INSIGHTS FROM CLUSTER FRONTLINE DEMONSTRATIONS



Zone		Districts	Total area (Mha)	Soil pattern	Major crops	Average rainfall (mm)	Temperature range (in °C)	Area (ha) under greengram (2020-21)
II _a	Transitional Plain of Inland drainage	Nagaur, Sikar, Jhunjhunu, and Part of Churu	3.69	Sandy loam, shallow depth red soils in depressions	Kharif- Pearl millet, Clusterbean, Pulses Rabi- Mustard, Gram	300-500	5.3-39.7	803304 (31.4)
II _b	Transitional Plain of Luni basin	Jalore, Pali, Sirohi, and Parts of Jodhpur	3.00	Red desert soils in Jodhpur, Jalore & Pali, Sierozems in Pali & Sirohi	Kharif- Pearl millet, Clusterbean, Sesame Rabi- Wheat, Mustard	300-500	4.9-38.0	375171 (14.7)
III _a	Semi-arid Eastern Plains	Jaipur, Ajmer, Dausa, and Tonk	2.96	Sierozems, eastern part alluvial, west north west lithosols, foot hills, brown soils	Kharif- Pearl millet, Clusterbean, Sorghum Rabi- Wheat, Mustard, Gram	500-700	8.3-40.6	296001 (11.6)
III _b	Flood prone Eastern Plain	Alwar, Dholpur, Bharatpur, Karoli, and Sawai Madhopur	2.77	Alluvial prone to water logging, soils of recently alluvial calcareous nature	Kharif- Pearl millet, Clusterbean, Groundnut Rabi- Wheat, Barley, Mustard, Gram	500-700	8.2-40.0	146 (0.01)
IV _a	Aravalli hills and Sub-humid Southern Plains	Bhilwara, Rajasamand, Udaipur, Chittorgarh, and Parts of Sirohi	3.36	Soil are lithosols at foot hills & alluvial in plains	Kharif- Maize, Pulses, Sorghum Rabi- Wheat, Gram	500-900	8.1-38.6	8677 (0.34)
IV _b	Humid Southern Plains	Dungarpur, Udaipur, Banswara, Chittorgarh	1.72	Predominantly reddish medium texture, well drained calcareous, shallow on hills, deep soils in valleys	Kharif- Maize, Paddy Sorghum, Blackgram Rabi- Wheat, Gram	500-1100	7.2-39.0	207 (0.01)
V	Humid south Eastern Plain	Kota, Jhalawar, Bundi, Baran, and Parts of Sawai Madhopur	2.70	Black soils of alluvial origin, clay loam, groundwater salinity	Kharif- Sorghum, Soybean, Rabi- Wheat, Mustard	650-1000	10.6-42.6	141 (0.01)

Source: https://rajas.rajasthan.gov.in/PDF/121202251359PMAgro_Zones.pdf. Assessed on 20.05.2024.



Fig. 4 'IPM 02-3' greengram in CFLDs at Ajmer district

2.1 Greengram cultivation in different agro-climatic zones of Rajasthan

Among ten agro-climatic zones in Rajasthan, six are the most important for greengram cultivation. The greengram is one of the most prolific pulse in western Rajasthan and adjoining areas of eastern plains. Nagaur, Sikar, Jhunjhunu, Churu, Bikaner, Jaisalmer and Jodhpur districts of Rajasthan, together contributes about 63% area of greengram. The productivity in these regions is low due to frequent moisture stress and crop exposure to other abiotic stresses especially in soil and water. The soils are light in texture with low organic matter and of poor water holding capacity. The next region is irrigated plains of Hanumangarh and Sriganganagar which contributes about 11% of greengram area. The soil area is calcareous with high deposits of soluble salts. The transitional plain of luni basin stretching across the districts of Jalore, Sirohi, Pali and Jodhpur and semi-arid plain of Ajmer, Jaipur, Dausa and Tonk together contribute about 26.3% of greengram area. This region is relatively more productive due to better irrigation facilities and also relatively better rainfall. The soils are medium to deep with intermitted gravels in the profile. Flood prone eastern plains, Aravalli hills and southern plains, humid southern plains have very little or insignificant area under greengram.



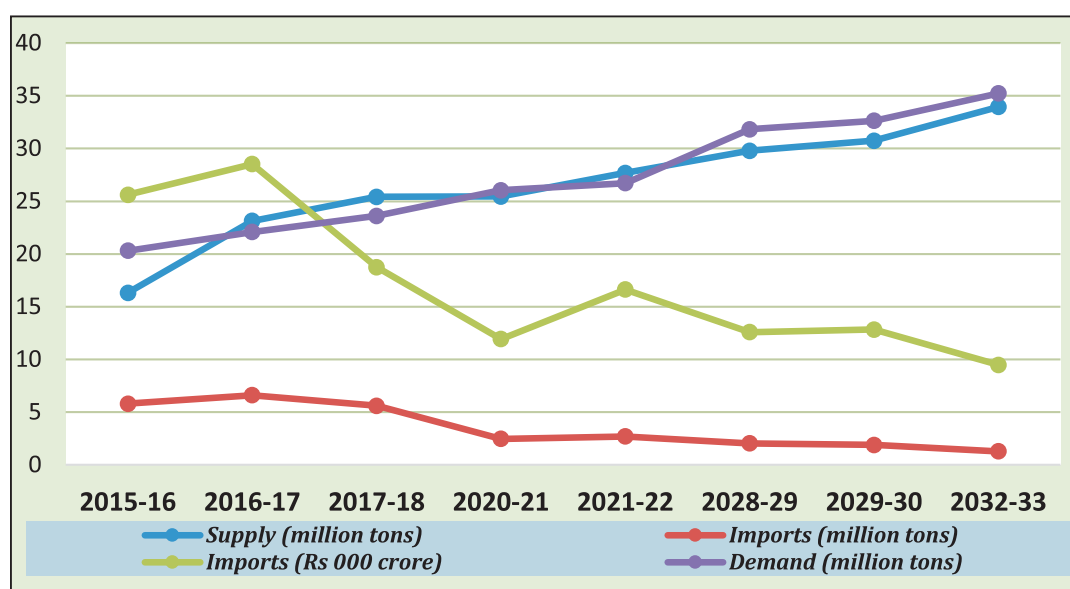
Fig. 5 Intercultural operations at farmer's field in Tonk district



2.2 Demand and supply of pulses

India is the largest producer and consumer of pulses in the world, constituting 28% of the world's total production and 30% of the world's total consumption of pulses in 2020, respectively (Food and Agricultural Organization (FAO), 2021). NITI Aayog Report (2018) on “Strategy for New India @75” highlighted a significant disparity within India's economic landscape. It revealed that despite agriculture engaging nearly 49% of the country's total workforce, its contribution to the Gross Value Added (GVA) stood at a mere 15%. In contrast, 29% of China's workforce was employed in agriculture. Inefficient extension delivery systems have led to the presence of large yield gaps as well and this calls for comprehensive modernization of agriculture and allied sectors. Yield gaps exist at two levels in India. First, there is a gap between best scientific practices and best field practices. The second gap exists between best field practices and the average farmer practices. There exist significant yield gaps both amongst and within states. Yield gaps have been found to exist in even highly productive states such as Punjab. Closing these gaps provides an opportunity to enhance productivity and incomes significantly. This further implies that states with low productivity (or large yield gaps) have significant potential for catch-up growth in their productivity levels.

The Working Group of NITI Aayog on Demand and Supply Projection of Agricultural Commodities estimated a consumption demand of 35.23 million tons in 2032-33 (Fig. 6). The deficit in demand and supply are met through imports which is about 14% global trade of pulses. Over the years, this deficit has reduced substantially due to significant increase in pulses production after 2013-14. However, being largely rainfed crops and grown in stressed conditions, intermittent productivity shocks are not uncommon which demands for imports. In order to meet the projected demand of 35.23 million tons of pulses by 2032-33, a growth of 4.2% per annum is required. To ensure the self-sufficiency, pulse requirement of the country is projected to be around 50 million tons by 2050, implying a 4.2% annual growth in its production



Source: NITI Aayog, 2018.

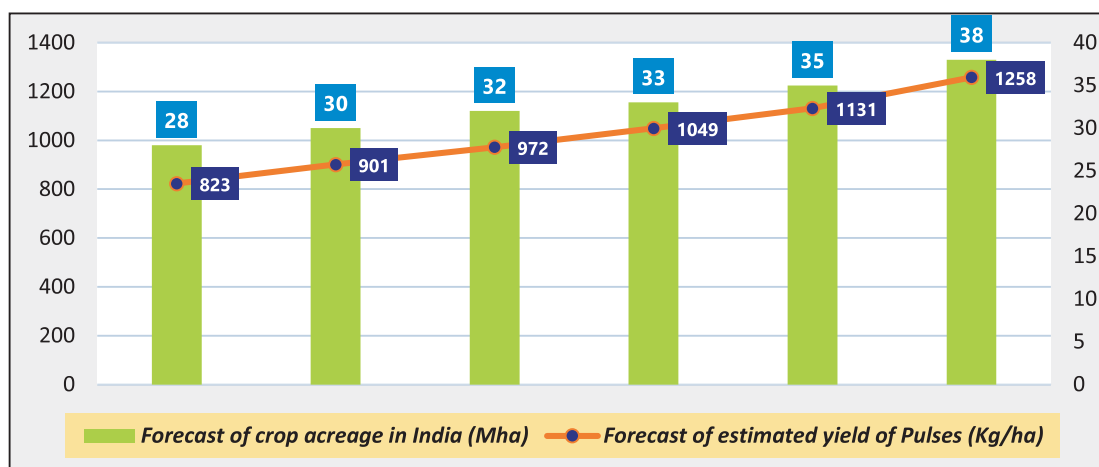
Fig. 6 Demand, supply and imports of pulses (2015-16 to 2032-33)

(Gosh *et al.*, 2023). The gap in domestic consumption demand and supply is met through imports of pulses from Myanmar, Canada, Australia, African countries and others. According to FAO estimates during 2022, India imported about 2.41 million tons of pulses from overseas during 2022. Greengram and blackgram (*Vigna mungo* L. Hepper) are among the major pulses imported by India and around 80% of India's imports are sourced from Myanmar (Varma *et al.*, 2023).



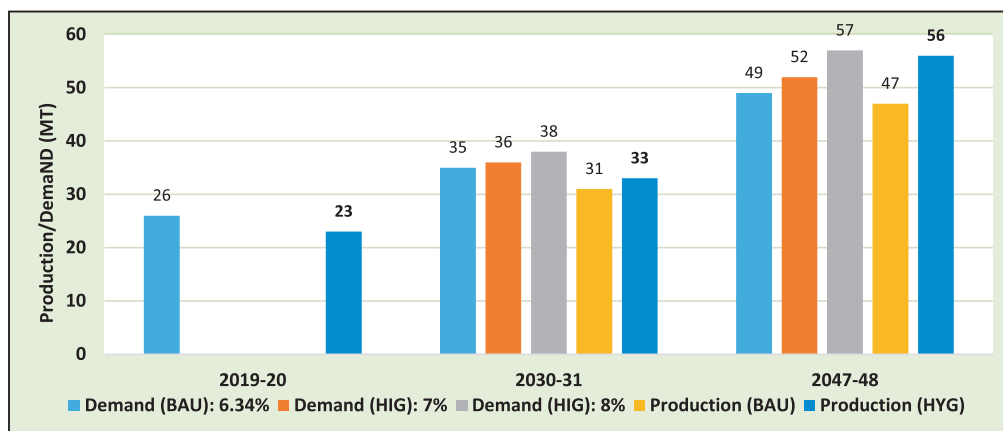
Fig. 7 'MH-421' under CFLDs at farmer's field in Nagaur district

NITI Aayog Working Group (2024) on “Crop Husbandry, Agriculture Inputs, Demand & Supply” estimated the demand of pulses at 49-57 million tons by 2047-48 under different income growth scenarios. The yield of pulses in India is currently low, which is projected to increase to 1258 kg/ha in the business as usual (BAU) scenario and 1485 kg/ha in the high yield growth (HYG) scenario (Fig. 8). By 2047-48, pulses production is likely to be more than double to 47-56 million tons. The demand of pulses for direct consumption is projected to double from 17 million tons in 2019-20 to 34 million tons in 2047-48 in the BAU scenario and 49-57 million tons under HIG scenario in 2047-48 (Fig. 9).



Source: NITI Aayog Working Group Report (2024)

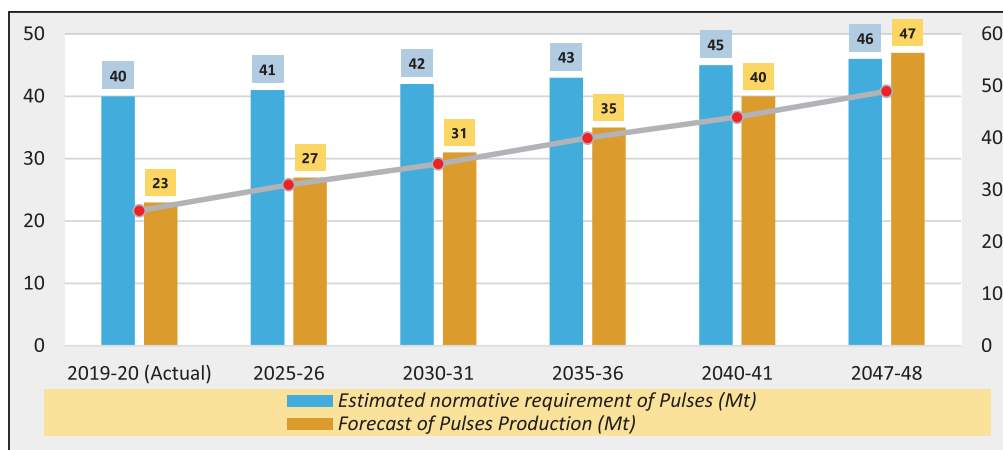
Fig. 8 Projections of pulses acreage and productivity in India



*(Food demand & Production: Business as Usual (BAU): High Income Growth (HIG)& High Yield Growth (HYG).
Source: NITI, Aayog Working Group Report (2024).

Fig. 9 Demand and production of Pulses in India

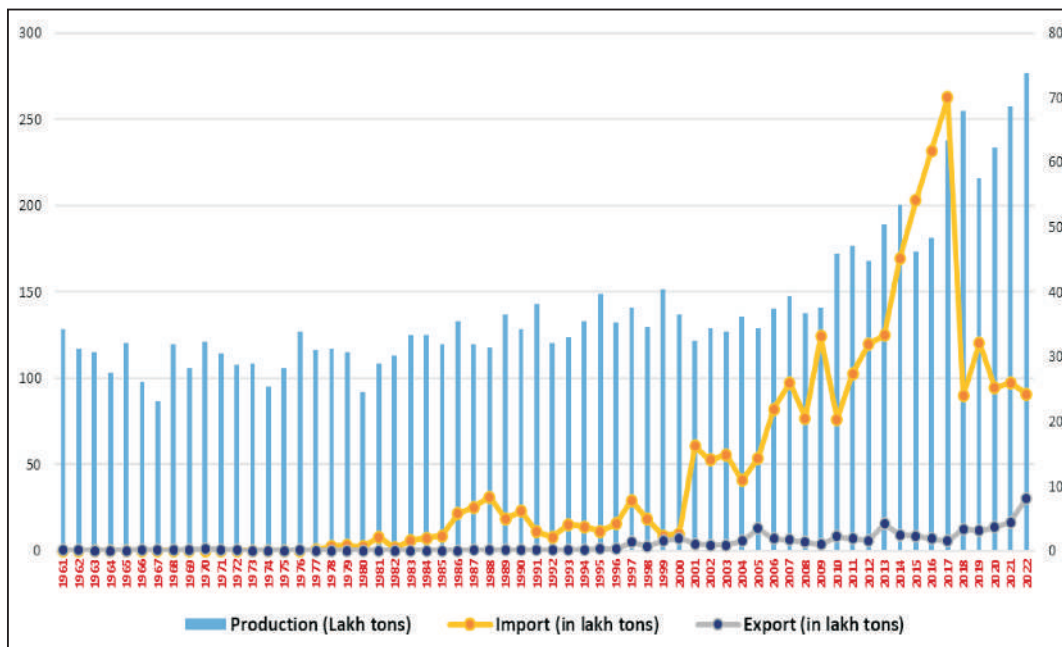
The gap is likely to persist in future in the absence of yield improvements and higher acreage to pulses. In the HYG scenario, pulses production will suffice to meet the growing demand. The area under pulses is projected to increase at 1.10% per annum as compared to 1.69% during 2011-12 to 2019-20 (Fig. 10). If the current trend in pulses area continues, and yield growth accelerates there is likelihood of achieving self-sufficiency in pulses.



Source: NITI Aayog Working Group Report (2024)

Fig. 10 Projections of pulses supply/production and demand in India

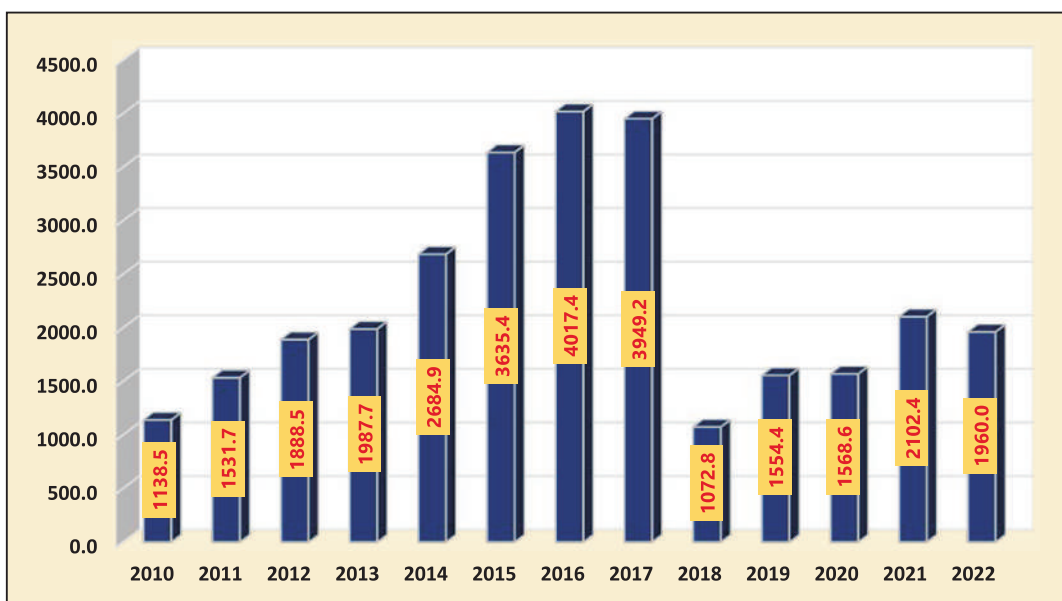
Due to joint efforts of stakeholders and strong support from policy and price triggers, the production of pulses in India, which had previously been hovering around 12-13 tons during mid-nineties, and 17-18 million tons in 2015-16, observed a significant turn around and increased to the highest-ever level of 27.66 million tons in 2022 (FAO 2024). The pulses import during 2016-17 was 6 to 7 million tons which reduced after 2015-16 but the country is still importing 2.4 million tons of the grain legumes (Fig. 11) in spite of significant breakthrough in pulses production post 2018-19.



Source: FAOSTAT statistical database, assessed on 5th April, 2024.

Fig. 11 Trend of pulses production, import and export in India (1961 to 2022)

The recent spike in pulses imports bill of \$1960 million in 2022 (FAOSTAT 2022) is putting challenges against the self-sufficiency in pulses (Fig. 12). Hence, increasing the domestic production of pulses is the long-term solution to meet the consumption demands of people. However, these are two challenges. Firstly, the luxury of area expansion which was the major driver for the success of Technology Mission on Oilseed and Pulses (TMOP) has dried up due to similar priority settings for oilseeds, the main



Source: FAOSTAT, 2010-2022.

Figure-12 Value of pulses imports (\$ million) in India (2010 to 2022).



competing crops with pulses. Secondly, the price signals, technology diffusion and incentivization of high productive and high value crops still forces these nutritionally rich crops to be grown under resource and plant nutrient starved conditions.

Nevertheless, the projections show that country need to produce about 49-57 million tons of pulses by 2047-48 to meet the consumption demand of population (NITI Aayog, 2024). This calls for augmenting the pulse production at higher pace than the current levels. Pulses production in India faces sharp year to year fluctuations causing higher price spike and price crash.

2.3 Pre and post cluster FLDs scenario

Since the beginning of the Green Revolution, the production performance of pulses has been low than other staple crops with some improvements in recent years. Between 1950-51 and 2015-16, production of pulses could increase only by 95.6% as compared to 455% in cereals and 390% in oilseeds in the country (NITI Aayog, 2018). Lingareddy (2020) noted that while the production of other food crops such as rice and wheat rose by over 225% and 808% respectively in the Triennium Ending (TE) 2013-14 from the TE 1960-61, pulse production increased only by 47% and their yield increased by 45% (from 518 to 750 kg/ha) in the same period. The population grew at faster rate than the rate of increase in pulses production in same period. Consequently, per capita availability of pulses declined from 60.54 g/day in 1950-51 to 43.83 g/day in 2015-16 against the minimum requirement of 68.49 g/day/capita (ICMR norms for sedentary activity). India witnessed a rapid rise in pulses production after reaching to 27.66 million tons in 2022 (Fig. 11). The demographic change characterized by increase in population, life expectancy and women's participation in the workforce has led to an increasing demand for diverse food items, away from staples, toward fruits and vegetables, dairy and meat and processed foods of higher value (Barrett et al. 2012). According to final estimates of MA&FW, New Delhi, India produced a total of 332.29 million tons of food grains in 2023-24,



Fig. 13 'IPM-2-14' greengram under CFLDs in Jaipur district

marking an increase of 80.75 million tons (32.10%) compared to 251.54 million tons in 2015-16. This growth supports the livelihoods of over 50 million farmers and their families. Pulses play a significant role, which contribute 7.29% to India's total food grain production. In 2023-24, India produced 24.24 million tons of pulses, which was decreased by 1.81 million tons from 26.05 million tons in 2022-23. However, compared to pre-CFLD period in 2015-16, when production was 16.32 million tons, the GOI initiatives to enhance the pulse production including CFLDs has resulted in a significant growth by 48.4% during 2023-24 (24.24 million tons).

In the light of the twin objectives of achieving food and nutritional security while enhancing income for rainfed farmers', the government has prioritized harnessing the potential of pulses. The CFLDs on pulses was initiated and implemented in the country with the help of the KVKs. The increase in yield is partly attributable to introduction of new pulse varieties, demonstration of new methods of cultivation of pulse crops and technologies related to plant protection, soil management, etc., under the framework of CFLDs. In 2015–16, however, phenomenal increase in prices of 40% in Wholesale Price Index (WPI) caused sharp increase in farm gate prices also which led to substantial increase in production of pulses. A country that has been producing an average of 16.1 million tons of pulses in the past decade produced 24 million tons in 2016–17. The performance of CFLDs on pulses has improved significantly. In 2016-18 pulses area increased 23% with 29.0% increase in production and 8.1% increase in yield over 2013-15. Impressive increase in area, production and yield under the major pulse crops has been observed post CFLD implementation. The change ranged from 5.4% gain in area under lentil to 67.4% for blackgram. There has been impressive gain in production, ranged from 34% for greengram to 81.6% for blackgram. Similarly, the positive change is observed in yield which ranged from 5.2% for greengram to 47.4% for lentil. In the major pulse growing states, with an area of more than 1 million ha, it is observed that the area under pulses has increased tremendously (Kar et al. 2020).



Fig. 14 Tractor drawn power sprayer demonstration at farmers' field in Tonk district



2.4 Individual FLD versus cluster FLDs

Organization of FLDs in clusters is a novel approach to influence not only the participating farmers' but also neighboring farmers. Therefore, it can be deduced that cluster FLDs serve as an effective extension intervention, showcasing the production potential of enhanced technologies in pulse crops directly on farmers' fields (Singh *et al.*, 2020). Several factors contribute to the attainment of farmers' group functions, including enhancing the learning process, facilitating cooperative action and networking, and providing assistance for production units (Kementan, 2013). Farmers' group gave opportunity for farmers to motivate them to be better in managing their own farming activities through social interaction (Spector, 2006). Farmers' will be able to share their experience and information among themselves. Interaction will lead farmers to share knowledge and enable them to learn from each other and making better decision for their farming activities. Thus, the CFLDs offer distinct advantages over the individual farmer approach.

A. Enhanced impact and reach

Scalability: CFLDs are implemented in cluster approach (a number of villages) rather than isolated fields, allowing for the demonstration of improved practices to a larger number of farmers' simultaneously. This scalability ensures a wider reach and more significant impact on the farming community.

Community learning: Through conducting demonstrations in clusters, CFLDs foster a community-based learning environment. Farmers' can learn from each other's experiences, share knowledge, and collectively adopt new technologies, leading to a more cohesive and supportive agricultural community.

Need based solutions and farmer's interest/preferences are met: Before going to implement, needs of farming community are identified by conducting Participatory Rural Appraisal (PRA) and Participatory



Fig. 15 Farmers group at field day of CFLDs on 'IPM-02-03' greengram at Jodhpur district

Learning and Action (PLA). In this exercise, farmers' problems have to be discussed and identified, need identification, preparation of resource inventory and prioritization of possible alternative technological solution in participatory way etc. be documented for efficient execution of programme. Also, farmers' preferences taken for future larger adoption and success of program.

B. Improved resource utilization

Efficient resource allocation: Resources such as seeds, fertilizers, and technical expertise can be more efficiently distributed and utilized in a clustered approach. This maximizes the benefits of the available inputs and extension services.

Cost-effectiveness: Conducting demonstrations in clusters reduces the per-unit cost of extension services and inputs, making the program/schemes more cost-effective compared to individual FLDs.

C. Better monitoring and evaluation

Enhanced monitoring: Cluster demonstrations make it easier for extension workers and scientists to monitor and evaluate the performance of the demonstrations. Frequent visits and interactions are more manageable within a cluster, ensuring better support and feedback from partner farmers'/peers.

Data collection: Collecting data on crop performance, farmers' feedback, and adoption rates is more streamlined in a clustered approach. This helps in more accurate analysis and assessment of the impact of the demonstrated technologies.



Fig. 16 Monitoring of CFLDs by Government officials



D. Increased adoption rates

Peer influence: Farmers are more likely to adopt new practices when they see their peers benefiting from them. The cluster approach leverages peer influence and social proof to encourage wider adoption of improved technologies.

Demonstration of success: A cluster-based approach provides a more comprehensive and convincing demonstration of the success of new technologies. Seeing the collective improvement in yield and profitability within a cluster can motivate other farmers in the region to adopt similar practices.

E. Holistic development

Integrated approach: CFLDs often involve integrated approaches to farming, addressing multiple aspects such as crop management, soil health, pest control, water management, and more issues. This holistic approach can lead to more sustainable and resilient farming systems.

Collaborative solutions: Challenges and issues can be addressed collectively in a cluster. Farmers' can collaborate to find solutions, share resources, and support each other, leading to more innovative and effective farming practices.

3. Government initiatives to enhance the pulse production

3.1 Cluster Frontline Demonstrations

The National Development Council (NDC) in its 53rd meeting held on 29th May, 2007 adopted a resolution to launch a Food Security Mission to boost food grain production in India. To operationalize this revolution, a centrally sponsored scheme, National Food Security Mission (NFSM), was launched in October 2007. The Cluster FLDs on Pulses were included during rabi 2016-17 through KVKs in the country. The key component of the programme included analysis of district-specific production constraints, preparing technology modules for each district, knowledge and skill upgradation of identified KVKs and extension workers, FLDs in clusters and field monitoring. The objectives of the scheme were:

- To demonstrate improved and proven production technologies of pulses in clusters on the farmer's field under different agro-climatic conditions.
- To popularize newly released varieties & notified technologies for varietal diversification and efficient management of resources.
- To bring synergy among planners, researchers, farmers', and industries for interface through seminars/symposiums on emerging themes of importance in the field of pulses production for deciding strategies for pulse development.
- Restoring soil fertility status through addition of soil nitrogen by including pulses in cropping system.
- Enhancing farm level economy (i.e. farm profits) to restore confidence amongst the farmers' with increasing the seed replacement rate under pulses crop.

The following strategies were also laid out for meeting the specific objectives:

- Focus on low productivity and high potential districts including cultivation of food grain crops in rainfed areas.
- Agro-climatic zone wise planning and cluster approach for crop productivity enhancement.
- Implementation of cropping systems-centric interventions in a mission mode approach through active engagement of all stakeholders at various levels.
- Promotion and extension of improved technologies i.e. seed, micro-nutrients, soil amendments, weed management, micro irrigation devices along with capacity building of farmers'.



Fig. 17 'IPM-02-3' greengram under CFLDs in Tonk district

From 2016 to 2022, CFLDs were conducted on 4,277 ha, involving 10,101 farmers across 25 districts in 9 diverse agro-climatic zones of Rajasthan (Table-2). These demonstrations implemented comprehensive packages of practices for greengram cultivation. This included the use of newly developed varieties (Table-3), optimized sowing methods, seed treatment, integrated nutrient management (INM), application of micronutrients, bio-fertilizers, integrated pest, disease management etc.

Table-2 CFLDs conducted on greengram production technology (2016 to 2022)

S.No.	Year(s)	Area (ha)	Number of CFLDs	Yield of CFLDs (q/ha)	Total quality seed produced (Q)
1.	2016	417	1038	8.96	3736.3
2.	2017	700	2579	7.47	5229.0
3.	2018	1070	2579	7.07	7564.9
4.	2019	475	1136	7.61	3614.7
5.	2020	420	1014	7.93	3330.6
6.	2021	355	850	7.51	2666.0
7.	2022	840	1968	7.44	6249.6
Total/average		4277	10101	7.66	32391.2

Table-3 Improved greengram varieties and their attributes

S.No.	Variety (s)	Year of release	Average yield (q/ha)	Characteristics
1.	MH-421 (Early)	2014 (CVRC) Haryana	10-12	➤ Resistant to Mungbean Yellow Mosaic Virus (MYMV) ➤ Medium bold and shining green seeds. ➤ Recommended for North western plain zone/central zone (Western Uttar Pradesh, Rajasthan, Delhi, Haryana) for spring and summer cultivation. ➤ Crop matures in 60-61 days
2.	MH-1142 (Early)	2020 (CVRC) Haryana	Summer-10-12 Kharif-14-16	➤ Notified for kharif season in North West and North East Plain zones of India (Uttar Pradesh, Punjab, Haryana, Delhi, Rajasthan, Uttarakhand, Bihar, Jharkhand, West Bengal and Assam) ➤ High yielding, disease resistant, pods are black and seeds are medium sized green and shiny. ➤ Moderately resistant to anthracnose and powdery mildew and resistant to MYMV diseases ➤ Crop matures in 60-65 days
3.	IPM-410-3 (Shikha) Mid-late (Medium duration)	(2016) Uttar Pradesh	11-12	➤ Highly resistant to MYMV ➤ Recommended for North West Plain Zone, Central Zone (Rajasthan, Punjab, Haryana, Delhi, Himachal Pradesh, Uttarakhand, Jammu & Kashmir, Madhya Pradesh, Maharashtra & Gujarat). ➤ Suitable for summer and spring season ➤ Crop matures in 65-70 days
4.	IPM 205-7 (Virat) (Extra early)	2016 (CVRC)	10-11	➤ Highly resistant to MYMV ➤ Recommended for South zone & Central zone (Andhra Pradesh, Tamil Nadu, Madhya Pradesh & Gujarat). ➤ Crop matures in 52-56 days
5.	Gujrat Moong-6 (Late)	2018 (CVRC)	11-12	➤ Bold seeded, long pod, determinate growth habit with synchronize maturity and good quality for marketable as well as cooking traits. ➤ Pods mature uniformly. ➤ Resistance to MYMV & <i>Cercospora</i> leaf spot (CLS). ➤ Recommended for cultivation in kharif and summer seasons of Gujarat, North eastern hill zone. ➤ Crop matures in 70-75 days
6.	Gujarat Moong-7 (Long duration)	2019 (SVRC) Gujarat	9-12	➤ Indeterminate growth habit with medium seed size and shiny green seed colour, better market and cooking quality. ➤ It has high yield potential and resistant against MYMV disease. ➤ Recommended for Gujarat. for kharif and summer seasons ➤ Crop matures in 75-80 days



S.No.	Variety (s)	Year of release	Average yield (q/ha)	Characteristics
7.	PDM 139 (Samrat) (Early)	2001, SVRC (Uttar Pradesh)	10-12	➤ Early maturity ➤ MYMV resistance ➤ Shining green seed ➤ Recommended for Uttar Pradesh ➤ Crop matures in 58-62 days
8.	IPM 02-3 (Early)	2009 (CVRC)	11	➤ Large seeded ➤ Photo and thermo-insensitive with highly resistance to yellow mosaic disease (YMD). Recommended for North West Plain Zone in kharif & spring season ➤ Crop matures in 62-68 days
9.	IPM 02-14 (Early)	2010 (CVRC)	11	➤ Highly resistant to YMD ➤ Recommended for South Zone in kharif & spring season ➤ Crop matures in 60-65 days
10.	MH 2-15 (Sattaya) (Medium late)	2008 (CVRC)	10-13	➤ Resistant to MYMV and CLS ➤ Recommended for North western plain zone /Central zone (Delhi, Haryana, Rajasthan, Western Uttar Pradesh) in kharif season. ➤ Crop matures in 67-72 days
11.	GAM 5 (Early)	2018 (SVRC) Gujarat	18-19	➤ Resistant to YMV ➤ Recommended for Gujarat in summer & kharif season ➤ Crop matures in 60-65 days
12.	SML 668 (Early)	2008 (CVRC)	10-11	➤ Resistant to MYMV ➤ Recommended for kharif season in Punjab. ➤ Crop matures in 60 days
13.	GM-4 (Early)	2002 (SVRC) Gujarat	12.5-13	➤ Suitable for kharif and summer ➤ Resistant against <i>Microphomina</i> blight ➤ Synchronous maturity ➤ Early in maturity ➤ High protein content (22.7%) ➤ Bold seed (4.27g/100 seeds) ➤ Crop matures in 60-65 days
14.	RMG 492 (Medium)	2003 (SVRC) Rajasthan	9-10	➤ Moderate tolerance to drought and web blight. ➤ Recommended for Rajasthan for Kharif and Zaid. ➤ Crop matures in 67-70 days ➤ Seed test weight is 41 gm.

Source: Directorate of Pulses Development, Bhopal (2017-18).

4. Methodology/Approach adopted

The CFLD is a form of applied research to demonstrate the latest notified/released varieties along with full Package of Practices (PoP) on cluster basis in farmers' fields. CFLDs aimed to show the potentiality of the technologies to participating farmers', neighboring farmers' and to analyze the production performance of the technologies for scientific feedback. Present FLDs have been conducted in the cluster mode, in which one or more than one village have been constituted to form a cluster of 10 ha area. For individual farmer, CFLD restricted to 0.4 to 0.8 ha. KVKs focused to choose the interior areas; where the farmers' have been deprived of demonstrations conducted by extension agencies. Hence, CFLDs on greengram production technology were conducted by 34 KVKs in 25 districts in 9 agro-climatic zones of Rajasthan during 2016 to 2022 (Fig. 18). CFLDs were conducted at 10101 partner farmers' fields. Full packages of practices of greengram including newly developed varieties, sowing methods, seed treatment,

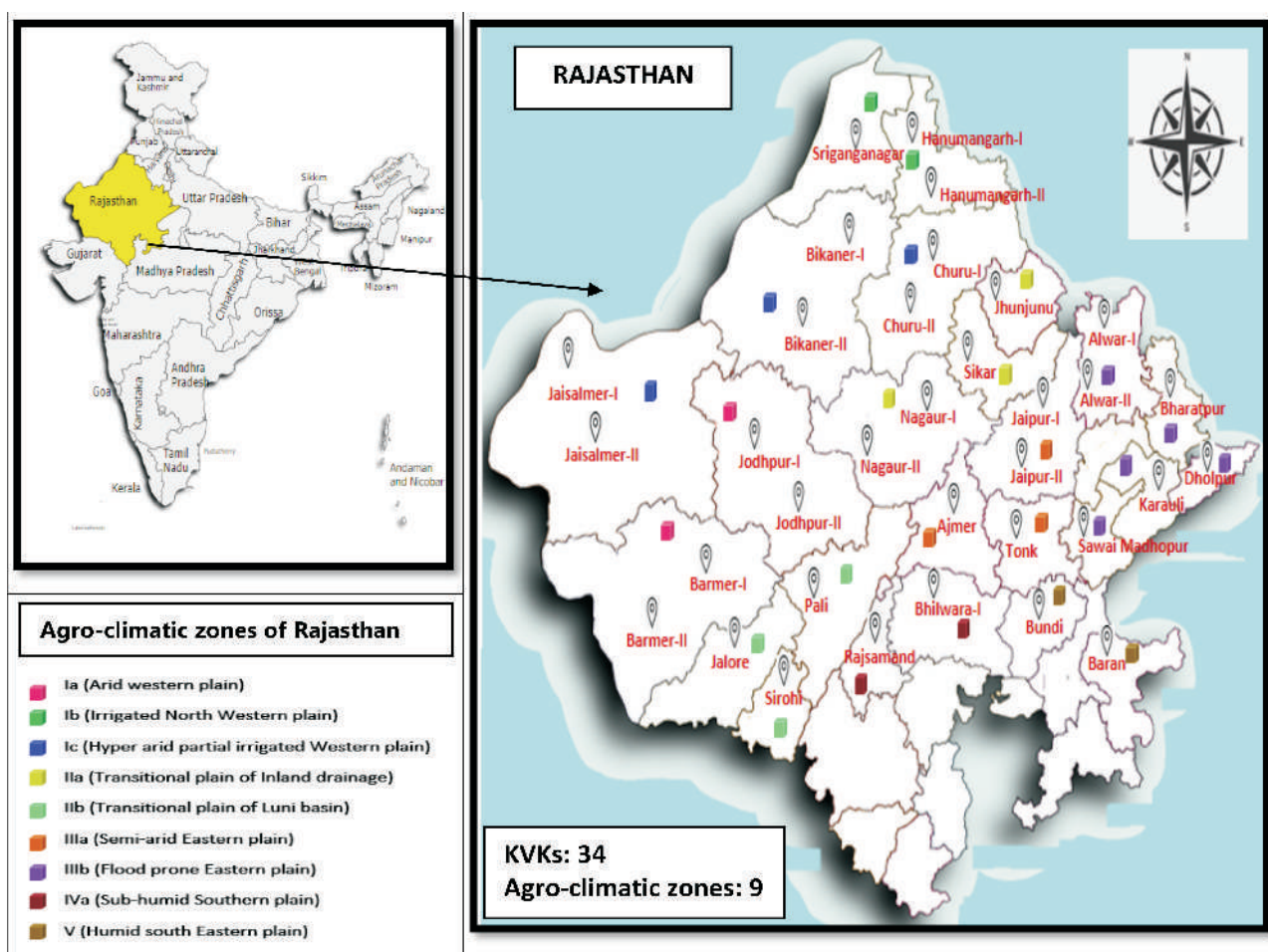


Fig. 18 Locale of the study in Rajasthan, India



Integrated Nutrients Management (INM), use of micronutrients, bio-fertilizers, integrated pest and diseases management, etc. were implemented. The attributes of varieties of greengram demonstrated are presented in (Table-3). The yield gaps were computed before the execution of the program. Identified CFLDs sites were geo-tagged for the location. Since the seed is critical input for organizing CFLDs, hence latest varieties of greengram released within 10 years were grown. Chemical fertilizers were not allowed as input under CFLDs. However, payment of various operations/services and inputs (seed, bio-fertilizers, soil ameliorants, micro-nutrients) were made admissible. Farmers' themselves applied the recommended dose of chemical fertilizers to attain the potential yield. The CFLDs were conducted in close supervision of the experts of the KVKs. Timely field visits were also made to the demonstration sites to resolve the field problem on the spot. For each CFLD, 10% budget was allocated to conduct the extension activities (field days, diagnostic visits, etc.). Crop cutting experiments were conducted by KVKs in presence of partner farmers', they also could learn and build the confidence among them. Timely monitoring was also done by the officials of ICAR-ATARI, Zone-II, Jodhpur, Directorate of Millet Development, Jaipur, Division of Agricultural Extension, ICAR, New Delhi and other associated institutes.

5. Impacts of CFLDs

5.1 Spread of quality seed

During 2016-2022, 10101 CFLDs of greengram were conducted on 4277 ha under 9 agro-climatic zones of Rajasthan. The average yield of CFLDs was realized as 766 kg/ha which produced 32391.2 q quality seed of greengram. Improved varieties have been demonstrated by KVKs at farmers' fields, hence the produce from those demonstration plots is the most suited for seed purposes rather than mass consumption as grain. During 2020-21, partner farmers kept 65.99% produce for seed purposes and 25% produce sold as grain in the market (Meena *et al.*, 2023). Assuming that all the 66% of produce retained as seed by the farmers was used as quality seed for the next crop season and one-fourth (25%) of the resultant greengram produce of next season would be used as seed for subsequent year/season. The likely area sown with quality seed produced through CFLDs varieties to total cultivable area of greengram in the state was estimated. The estimates suggested that about 13.4% to 53.8% of total greengram area could be sown with CFLDs seeds in subsequent years (Table 4).

Table: 4 Quality seed produced and expected area expansion through CFLDs (2016 to 2022)

Crop	Total produce (q)	If 66% of total produce used as seed		If total 100% produce is used as seed in next season, then estimated quantity of produce	Expected area covered (in ha)		Likely share (%) of area sown with quality seed in total cultivable area of the state	
		Quantity of seed (q)	Expected area covered (ha)		If 25% of next season produce taken as seed in second season	If 100% of next season produce taken as seed in second season	If 25% of second season produce used as seed	If 100% of second season produce used as seed
Greengram	32391.2	21378.2	118767.8	248116.7	344606.5	1378426.3	13.4	53.8

Average seed rate of greengram-18kg/ha; Average CFLDs yield: 7.66q/ha; Greengram area in Rajasthan during 2021-22 was 2560671 ha.

5.2 Yield and yield gaps

During 2016-2022, an area of 4277 ha was covered under CFLDs by 34 KVKs in 25 districts of Rajasthan. All KVKs conducted FLDs in cluster mode with full PoP of greengram. The results showed that CFLDs yield was 766 kg/ha, whereas FPs yielded 589 kg/ha. The yield from CFLDs exceeded from FPs by 30% (Table 5 and Fig. 19 & 20).

Results shows that CFLDs performed better in zone-Ib (934 kg/ha) followed by Zone-V (876 kg/ha). The study's findings reveal that the yield gap (%) varied significantly across different agro-climatic conditions (Fig. 20 and 21). Specifically, it ranged from 21.5% in the Transitional Plain of Inland Drainage (IIa) to 37.6% in the Transitional Plain of Luni Basin (IIb). The highest yield gap of 42.2% was observed under the Pali conditions followed by a 39.7% gap in Churu-II. The districts exhibited the highest yield gaps, indicating significant potentials for the improvement. The large gaps suggest that the current farming

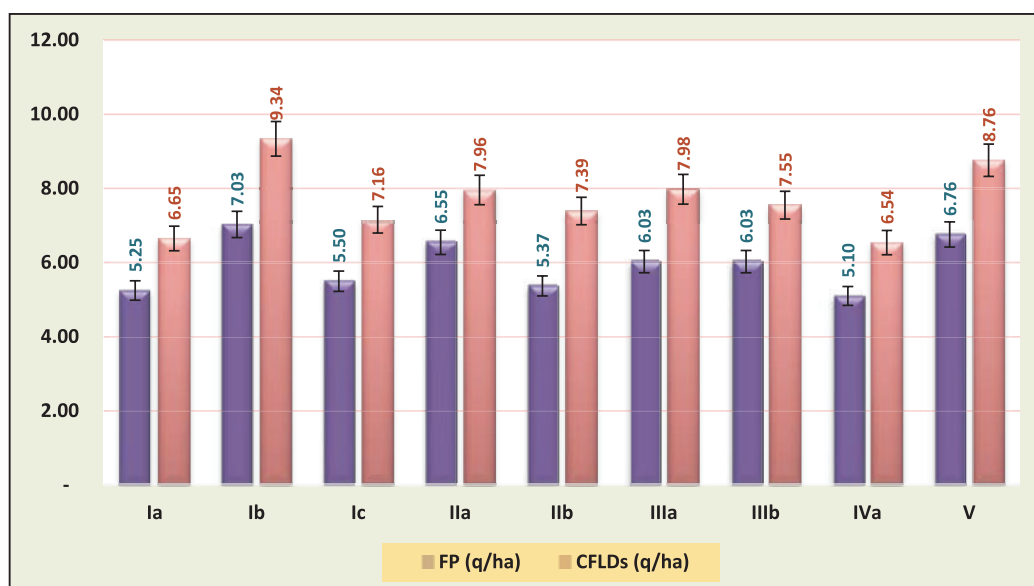


Fig. 19 Greengram yields under CFLDs and FPs (2016 to 2022)

practices in these areas are not fully utilizing the available agricultural technologies and practices. Addressing these gaps could substantially boost productivity and profitability. In contrast, the lowest yield gaps were found in Alwar-I conditions (15.3%) and Jodhpur-II conditions (17.4%). The lower yield gaps in these districts suggest that farmers are closer to achieving the potential yields, possibly due to better adoption of recommended practices and technologies. By focusing on these districts with the highest gaps and implementing targeted strategies, it is possible to significantly enhance greengram productivity and farmers' livelihoods. The variations in yield gaps across different regions highlight the need for localized approaches to agricultural extension and technical support. The district wise yields are presented in Table-5.

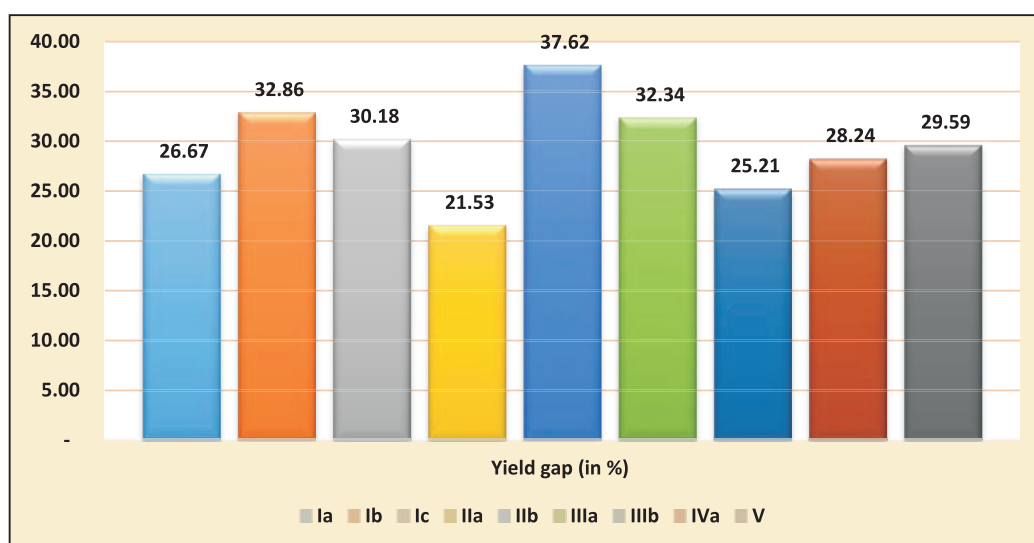


Fig. 20 Yield gaps in greengram (2016 to 2022)

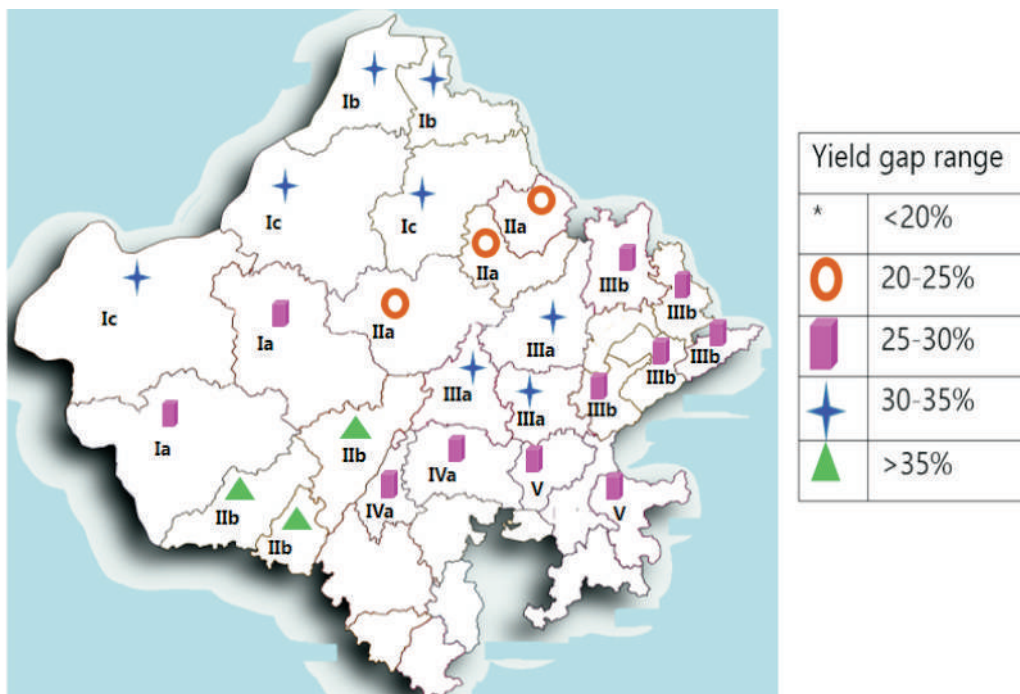


Fig. 21 Yield gaps in greengram across agro-climatic zones of Rajasthan

Table-5 Greengram yield in diverse agro-climatic zones of Rajasthan

KVKs/ Agro-climatic zones	Area (ha)	Number of CFLDs	FP (kg/ha)	CFLDs (kg/ha)	Yield increased (%)
Ia (Arid western plain)					
Barmer-I	165.0	304	450	597	32.6
Barmer-II	90.0	182	511	705	37.9
Jodhpur-I	140.0	350	595	718	20.6
Jodhpur-II	80.0	175	570	669	17.4
Total/Average	475.0	1,011	525	665	26.6
Ib (Irrigated north western plain)					
Hanumangarh-I	190.0	475	713	976	36.8
Hanumangarh-II	100.0	250	704	921	30.8
Sriganganagar	150.0	372	691	890	28.8
Total/Average	440.0	1,097	703	934	32.8
Ic (Hyper arid partial irrigated western plain)					
Bikaner-I	130.0	325	599	750	25.2
Bikaner-II	100.0	250	563	711	26.2
Jaisalmer-I	190.0	425	493	660	33.8
Jaisalmer-II	90.0	225	616	773	25.4
Churu-I	140.0	350	522	729	39.6
Churu-II	80.0	200	567	713	25.7
Total/Average	730.0	1,775	550	716	30.1



KVKs/ Agro-climatic zones	Area (ha)	Number of CFLDs	FP (kg/ha)	CFLDs (kg/ha)	Yield increased (%)
IIa (Transitional plain of inland drainage)					
Nagaur-I	121.0	303	606	716	18.1
Nagaur-II	80.0	200	689	851	23.5
Sikar	180.0	450	480	596	24.1
Jhunjhunu	220.0	550	814	983	20.7
Total/Average	601.0	1,503	655	796	21.5
IIb (Transitional plain of Luni basin)					
Jalore	210.0	499	533	742	39.2
Pali	198.0	445	510	725	42.1
Sirohi	200.0	500	567	750	32.2
Total/Average	608.0	1,444	537	739	37.6
IIIa (Semi-arid eastern plain)					
Jaipur-I	220.0	550	612	827	35.1
Jaipur-II	95.0	215	593	771	30.0
Ajmer	220.0	445	602	771	28.0
Tonk	166.0	337	600	809	34.8
Total/Average	701.0	1,547	603	798	32.3
IIIb (Flood prone eastern plain)					
Alwar-I	110.0	211	679	783	15.3
Alwar-II	100.0	247	604	737	22.0
Dholpur	34.0	85	350	460	31.4
Bharatpur	20.0	50	720	859	19.3
Sawai Madhopur	80.0	190	635	834	31.3
Karauli	110.0	275	559	759	35.7
Total/Average	454.0	1,058	603	755	25.2
IVa (Sub-humid southern plain)					
Bhilwara-I	110.0	275	503	652	29.6
Rajsamand	130.0	323	515	656	27.3
Total/Average	240.0	598	510	654	28.2
V (Humid south eastern plain)					
Baran	20.0	50	663	851	28.3
Bundi	7.2	18	712	946	32.8
Total/Average	27.2	68	676	876	29.5
Overall Total/Average	4,277	10,101	589	766	30.0

5.3 Performance of greengram varieties

The crop production operates as a business endeavor, thus the varieties we develop must exhibit the economic viability. The new varieties must demonstrate the capacity to yield optimal quality and quantity across diverse conditions and regions. Farmers' preferred varieties of greengram were provided to the partner farmers' as crucial inputs to showcase the production potential of greengram. Thus, 13 greengram varieties were demonstrated by KVKs in 9 agro-climatic conditions in Rajasthan. Fig. 22 exhibits that the RMG-492 variety proved to be the highest performer with an average yield of 983kg/ha followed by GM-4 (849kg/ha) and IPM-2-14 (811kg/ha). The CFLDs show that mass promotion of these varieties should be done by state department of agriculture.

Locally developed stress tolerant variety i.e., RMG-492 of medium duration (65-70 days) proved the most promising in yield as compared to other varieties. In general, the medium duration varieties performed better than extra early (<60 days) and late varieties (>70 days). The length of growing period in the soils of Rajasthan is limiting for long duration varieties (Table 3 and Fig. 22).

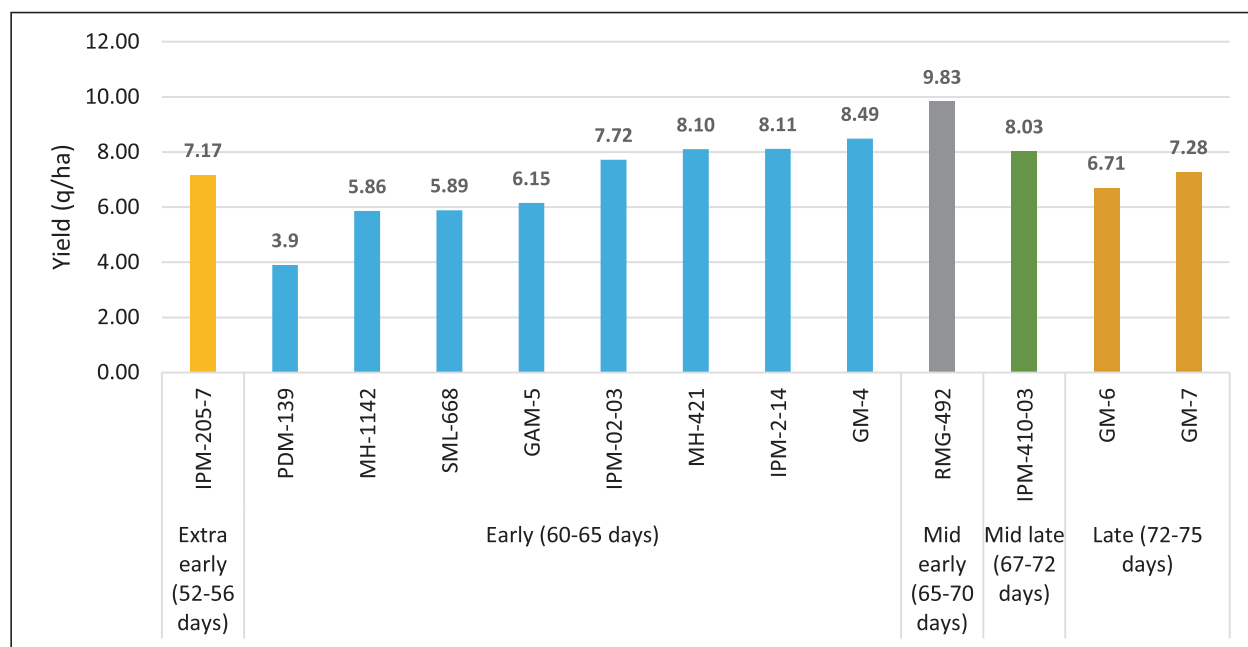


Fig. 22 Performance of greengram varieties in Rajasthan

5.4 Income augmentation

The demonstration of improved greengram varieties under full PoP led to an average yield of 766 kg/ha, compared to 589 kg/ha under FPs. This shows 30% increase (1.77 q/ha) through CFLDs. From an area of 4277 ha, total production enhanced by 7568.88 q. This produce was sold @ Rs. 5909.52/q. The gross return for greengram production was Rs. 45,266.99/ha. This could add Rs. 447 lakhs to the farm economy in Rajasthan (Table-6).



Fig. 23 Field day organized by KVK, Hanumangarh-I

Table-6 Economics of CFLDs and FPs of greengram (2016 to 2022)

KVK (s)	Economics of FP (Rs./ha)				Economics of CFLDs (Rs./ha)			
	Gross cost	Gross return	Net return	BC ratio	Gross cost	Gross return	Net return	BC ratio
Ia (Arid western plain)								
Barmer-I	12,925.00	25,830.67	12,905.67	1.97	14,520.83	33,890.17	19,369.33	2.31
Barmer-II	12,422.00	26,294.40	13,872.40	2.07	15,014.00	35,912.00	24,268.00	2.32
Jodhpur-I	14,165.00	34,820.80	20,655.80	2.43	15,546.00	42,528.00	26,982.00	2.71
Jodhpur-II	12,975.00	35,293.25	22,566.25	2.77	14,837.50	47,428.50	32,591.25	3.18
Average	12,788.04	26,525.29	13,772.68	2.03	14,575.54	34,492.89	20,519.18	2.32
Ib (Irrigated north western plain)								
Hanumangarh-I	15,211.00	42,680.81	27,469.81	2.79	17,412.57	52,991.53	35,514.67	3.03
Hanumangarh-II	15,186.40	43,612.60	28,426.40	2.87	18,325.60	57,337.80	39,048.20	3.12
Sriganganagar	15,508.92	41,528.27	26,019.35	2.77	16,984.36	53,298.05	36,313.69	3.29
Average	15,006.60	41,471.92	26,465.37	2.79	17,183.36	52,892.49	35,696.27	3.13
Ic (Hyper arid partial irrigated western plain)								
Bikaner-I	15,640.14	34,521.17	19,023.88	2.20	16,874.86	45,062.12	28,187.26	2.66
Bikaner-II	16,010.00	39,428.02	23,418.02	2.44	17,360.00	49,814.85	32,454.85	2.86
Jaisalmer-I	14,665.13	32,723.52	17,861.40	2.17	15,896.07	42,504.34	26,608.28	2.57
Jaisalmer-II	15,330.00	41,785.67	26,455.67	2.71	16,816.67	52,516.67	35,700.00	3.10
Churu-I	13,889.86	27,858.86	13,929.00	2.02	15,388.57	41,294.00	25,924.00	2.69
Churu-II	15,020.00	40,526.98	25,506.98	2.68	16,560.00	51,286.70	34,726.70	3.08
Average	14,656.75	34,143.40	19,481.90	2.29	16,078.12	44,975.75	28,900.73	2.75



POTENTIAL OF GREENGRAM IN RAJASTHAN

INSIGHTS FROM CLUSTER FRONTLINE DEMONSTRATIONS

KVK (s)	Economics of FP (Rs./ha)				Economics of CFLDs (Rs./ha)			
	Gross cost	Gross return	Net return	BC ratio	Gross cost	Gross return	Net return	BC ratio
IIa (Transitional plain of inland drainage)								
Nagaur-I	18,268.33	43,932.56	25,664.06	2.29	19,749.17	56,990.25	37,799.58	2.73
Nagaur-II	23,520.00	43,604.65	20,084.65	1.86	24,739.92	52,685.13	27,945.21	2.13
Sikar	16,464.29	48,860.39	32,396.11	2.94	18,564.29	59,221.43	40,657.14	3.17
Jhunjhunu	17,468.57	35,586.42	18,213.09	1.98	18,638.57	41,908.83	24,450.90	2.19
Average	18,139.76	41,573.24	23,457.24	2.27	19,668.74	50,854.87	31,600.98	2.55
IIb (Transitional plain of Luni basin)								
Jalore	20,103.89	30,751.90	10,568.57	1.56	21,757.67	46,605.27	24,847.62	2.19
Pali	17,960.71	33,585.60	17,318.46	1.85	17,808.92	43,841.00	26,032.09	2.45
Sirohi	16,007.72	34,963.40	19,973.24	1.97	18,683.92	47,000.60	28,316.68	2.29
Average	17,976.76	32,172.58	15,201.35	1.74	19,024.89	44,498.64	25,473.75	2.29
IIIa (Semi-arid western plain)								
Jaipur-I	12,964.14	38,686.03	25,721.88	2.95	14,632.29	50,131.42	35,499.13	3.38
Jaipur-II	16,059.40	35,422.80	19,357.40	2.30	17,882.00	45,462.60	27,560.60	2.65
Ajmer	19,743.57	38,819.38	19,075.81	1.96	22,198.57	52,580.07	30,643.45	2.36
Tonk	16,526.43	40,267.79	23,741.36	2.26	18,815.71	53,950.68	35,134.96	2.68
Average	16,232.61	38,068.51	21,834.83	2.35	18,314.31	50,272.35	32,019.96	2.74
IIIb (Flood prone eastern plain)								
Alwar-I	15,620.83	32,886.67	17,265.83	2.09	17,070.67	40,199.33	23,128.67	2.34
Alwar-II	16,145.82	40,132.47	23,987.24	2.47	18,650.44	50,794.83	32,144.48	2.72
Dholpur	19,927.50	52,169.25	32,241.75	2.69	20,680.00	62,157.75	41,477.75	3.06
Bharatpur	15,500.00	17,500.00	2,000.00	1.12	17,000.00	23,000.00	6,000.00	1.35
Sawai Madhopur	13,690.33	30,143.00	16,452.67	1.85	15,424.00	40,584.00	25,160.00	2.31
Karauli	18,457.50	34,960.00	16,502.50	1.12	20,361.50	45,750.00	25,388.50	1.26
Average	16,127.82	36,438.58	20,310.97	2.05	17,899.91	45,807.47	27,907.59	2.31
IVa (Sub-humid southern plain)								
Bhilwara-I	13,930.00	28,086.20	14,156.20	1.84	15,350.00	36,166.60	20,816.60	2.16
Rajsamand	16,917.00	31,290.67	14,440.33	1.85	18,431.17	40,067.67	21,636.50	2.17
Average	15,482.29	29,529.64	14,075.93	1.78	16,988.64	38,069.57	21,080.93	2.11
V (Humid south eastern plain)								
Baran	5,500.00	18,000.00	12,500.00	3.27	6,000.00	28,000.00	22,000.00	3.66
Bundi	21,181.00	41,448.00	20,261.00	1.96	23,155.00	55,030.00	31,875.00	2.38
Average	13,340.50	29,724.00	16,380.50	2.62	14,577.50	41,515.00	26,937.50	3.02
Overall Average	15,810.12	34,990.26	19,316.06	2.18	17,469.11	45,266.98	27,931.48	2.53

5.5 Area covered through quality seed produce

During 2016 to 2022, KVKs of Rajasthan conducted CFLDs on greengram in 4277 ha area which produced 32391.2 qt. of quality seeds. It is assumed that partner farmers retained 66% of their quality produce as seed for the next season, this seed of greengram could cover 5.03% area of 118767.8 ha in Rajasthan (Table-7). Moreover, there are many factors which decides the adoption of agricultural



Fig. 24 Crop cutting experiment at farmer's field

technologies alike of education, social participation, occupation, size of land holding, annual income, area under the seed program, market orientation, varietal replacement, production of quality seed, mass media exposure, and extension participation all play discernible roles in influencing the likelihood of adopting new seeds (Nagar *et al.*, 2022).

Table-7 Area coverage through quality produce of CFLDs

Year (s)	Yield (q/ha)	Area (in ha)	Produce (kg)	Area covered under greengram in Rajasthan (ha)*	Area (ha) covered (If 66% of produce taken as seed for next sowing @18 kg/ha)	Area covered in Rajasthan through seed produced under CFLDs. (If 66% produce of FLDs used as farmed saved seed @ 18 kg/ha)
2016	8.96	417	373632	2120352	13699.8	0.64
2017	7.47	700	522900	2249619	19173.0	0.85
2018	7.07	1070	756490	2465229	27737.9	1.12
2019	7.61	475	361475	2322998	13254.0	0.57
2020	7.93	420	333060	2549294	12212.2	0.47
2021	7.51	355	266605	2560671	9775.5	0.38
2022	7.44	840	624960	2332255	22915.2	0.98
Total	7.66	4277	3239122	16600418	118767.8	5.03

*Reports (2016-2022) Directorate of Economics & Statistics, Rajasthan Agriculture Statistics, Government of Rajasthan, <https://rajas.rajasthan.gov.in/Index.aspx>.



Fig. 25 Scientists-farmers interaction 'MH-421' greengram field in Nagaur district

A multifaceted interplay of socio-economic, educational, and agricultural factors influence the decision-making process of farmers with regards to seed replacement (Bhavani *et al.*, 2022). Policy makers and planners should consider these factors collectively to formulate effective strategies for promoting seed replacement and ensuring the successful adoption of improved agricultural practices.

5.6 Soil health improvement

Legumes are an important component of crop rotations and combinations. They require less fertilizer than other crops and are low carbon source of protein. Pulses have a direct positive impact on soil quality as they help feed soil microbes, which helps in improving soil health. Additionally, pulses are used as green manure and contribute in improving soil health, offering the possibility for a mixed/ intercropping system. Thus, pulses play a vital role in improving human health as well as soil health through their nitrogen fixing properties. Pulses get over 60% of their nitrogen from the atmosphere. This nitrogen is then fed into the soil and allows these legumes to share this nitrogen with nearby crops, essentially reducing the need for chemical fertilizers. This unique ability is called biological nitrogen fixation where they assimilate atmospheric nitrogen into plant-useable form of nitrogen. Zaidi *et al.* (2005) reported that greengram fixes 30-40 kg/ha of nitrogen in the field conditions. Taking this finding, it is estimated that through 118767.8 ha under CFLDs, 4750712.2 kg of nitrogen have been fixed in the fields. The approximate cost of urea for 45 kg of bag is Rs. 2200, however the subsidized current market price of urea is Rs. 242 for 45 kg per bag. Hence, the cost for one kg urea is Rs. 5.37, which was taken for the calculation as fixed by the Ministry of Chemicals and Fertilizers, GOI. During 2016 to 2022, total 3239122 kg of improved seeds of greengram were produced from these CFLDs. From the total produce, farmers retained 66% produce of CFLDs for next season (Meena *et al.* 2023). Hence, the area expansion through quality seed of greengram could be 118767.8 ha which could fix 4750712.2 kg of nitrogen in the soil. To supply the 4750712.2 kg nitrogen, 104515.6 q of urea was supposed to be applied in the soil. This could save Rs. 5.61 crores through CFLDs on greengram. As an indirect benefit, the CFLDs could save Rs. 45.45 crores (subsidy @Rs. 43.51/kg urea) which was supposed to be provided to the farmers by GOI for the application of 104515.6 q of urea (Table-8).



Table: 8 Nitrogen fixation in the soil and cost saving of urea through CFLDs

Year (s)	Quality seed produced (kg)	Total area (in ha) likely to be sown with the improved variety (Assuming 66% produce is taken as seed in next season @ 18 kg/ha)	Total nitrogen fixed @ 40 kg/ha	Urea required to supply the nitrogen (in kg)	Cost saving of urea (in crores)
2016	373632	13699.8	547993.6	1205585.9	0.64
2017	522900	19173.0	766920.0	1687224.0	0.90
2018	756490	27737.9	1109518.6	2440941.0	1.31
2019	361475	13254.0	530163.3	1166359.3	0.62
2020	333060	12212.2	488488.0	1074673.6	0.57
2021	266605	9775.5	391020.6	860245.4	0.46
2022	624960	22915.2	916608.0	2016537.6	1.08
Total	3239122	118767.8	4750712.2	10451566.9	5.61

5.7 Capacity building and extension activities

Training constitutes a foundation of KVKs' activities aimed at enhancing the proficiency and knowledge of farmers' and farm women across diverse domains such as planting techniques, irrigation, pesticide management, crop rotation, and post-harvest storage strategies, etc. These competencies empower farmers to augment yields, shield their crops from weather-induced adversities, and stabilize their incomes throughout the year. These educational endeavors also serve to enlighten families about the manifold



Fig. 26 Field day at 'IPM-02-14' greengram field in Jaisalmer district

benefits associated with the agriculture. KVKs have provided comprehensive training to partner farmers' encompassing the entire spectrum of PoP pertinent to greengram cultivation prior to initiating CFLDs. Over the course of seven years (2016-2022), a total of 529 trainings were meticulously organized, benefiting a substantial 14,131 farmers' and farm women. This initiative has had a significant impact on agricultural practices and community development in the region. Concurrently, over the same period, 823 extension activities, including field days, monitoring visits, diagnostic visits, etc., were organized, reaching out to 32,912 farmers' and farm women. Such concerted efforts emphasize the pivotal role played by the KVKs in disseminating agricultural knowledge and fostering sustainable practices within the farming communities.



Fig. 27 Field view of 'MH-421' greengram in Pali district



6. Challenges

In India, pulses are cultivated primarily under rainfed conditions and on marginal or relatively poor soils with minimum use of applied inputs. Studies suggest that many pulse farmers are subject to market fluctuations, often selling their crops at 20 to 30 % below the Minimum Support Price (MSP) (Reddy, 2021). A study of NITI, Aayog conducted in 2016 also highlighted farmers' low awareness levels and the lack of effective procurement under MSP (Subramanian, 2016). The major food crops, such as rice and wheat, have received significant incentives through MSP and procured well for Public Distribution System (PDS), leading farmers to prioritize these crops or cash crops like cotton and sugarcane. Pulses, on the other hand, have often been a secondary choice, mainly grown in rainfed areas. The slow growth in production of pulses is accompanied by wide regional variations, temporal fluctuations and unfavorable revenue terms of trade with fine cereals and oilseeds (Srivastava et al., 2010). In context of Rajasthan, there are many constraints hindering the production, marketing and post-harvest management of greengram. Some of the challenges being faced by farmers are:

- i. Extreme weather events, marked by drastic fluctuations in minimum and maximum temperatures beyond tolerable thresholds, induce flower abortion, accelerate the reproductive phase, and diminish grain yield.
- ii. During the monsoon season, edaphic factors like waterlogging are prevalent in crop cultivation. Greengram, being particularly susceptible to waterlogging, often leads to crop failures.
- iii. Variability in amount of rainfall, shortage of labour during peak hours of harvesting, grazing by stray animals, insufficient crop insurance coverage, inadequate research and extension support, delayed and less supply of seeds and irregular supply of inputs like fertilizer and plant protection chemical (excluding seeds) were the main production constraints faced by the greengram cultivators (Mahendra *et al.*, 2020).
- iv. Greengram exhibits lower productivity and yield potential compared to cereals, attributed to inadequate resource allocation and suboptimal nutritional conditions.
- v. The insufficient availability of seeds from improved varieties, coupled with a significant gap in the adoption of agronomic practices and recommended packages, exacerbates the challenges faced by farmers.
- vi. Fluctuations in market price, difficulty in maintaining quality standards, high transportation cost, lack of good storage facilities, cut in weight of the produce due to poor quality standard and delaying on payment by traders are the major marketing constraints faced by the cultivators (Mahendra *et al.*, 2020).
- vii. Greengram experiences sluggish growth, prolonged maturation periods, reduced yields due to poor seed set, and limited response to fertilizer application. Consequently, farmers are increasingly turning to alternative, more productive crops, resulting in a decline in greengram cultivation over time.
- viii. Damage inflicted by wildlife, such as the blue bull (*Boselaphus tragocamelus*), poses a significant threat to greengram cultivation, further exacerbating the challenges faced by farmers.

7. Innovations and learnings insights

CFLDs is an intensive learning activity wherein farm experts, extension workers and farmers'/farm women learn from each other. The participatory learning process involve all partners in planning, conducting demonstrations in fields and subsequent follow up. A well-organized CFLDs help scientists and extension workers in improving the knowledge, understanding and skills of farmers' leading to change in their attitude towards technology. Some of the reflections of the innovations and learning insights of farmers of Rajasthan is presented in following para:

A. Newly released varieties

In India, where over 80% of pulse cultivation are concentrated in rainfed environments, quality seeds of improved varieties are essential to boost the production (Chouhan *et al.*, 2016). Fortunately, quite good numbers of season specific varieties of pulses have been developed in recent times. They are high yielding, resistant to diseases and insect-pests, thereby proved their potential at farmers' fields and also under large scale demonstrations. It is established that improved varieties of pulses have been able to enhance productivity by 15-20% in almost all major pulse such as chickpea, greengram, blackgram and lentil. The level of increase in pigeonpea has been slightly lower to 10-12% (Dixit *et al.*, 2024).

Total of 13 improved varieties of greengram have been introduced and demonstrated at farmers' fields through CFLDs during 2016-2022. These varieties have proven their potential across diverse agro-



Fig. 28 Variety 'GM-7' at farmers' field in Raipur, Pali district



climatic conditions in kharif as well as in summer seasons. The successfully performing varieties are PDM-139, MH-1142, SML-668, GM-5, GA-6, GM-7, IPM-205-7, IPM-02-03, IPM-410-03, MH-421, IPM-2-14, GM-4, and RMG-492.

B. Strategic shifts from kharif to summer cultivation

Greengram is predominantly cultivated in kharif season under rainfed conditions in Rajasthan. It has been a formidable challenge experienced by farmers. The crop is exposed to heavy rainfall at its maturity stage leading to crop failures. Realizing the hardships of the farmers' the KVKs have convinced and motivated the farmers to cultivate the greengram in summer season in the southeastern districts of Rajasthan viz., Sawai Madhopur, Kota, Banswara, Dungarpur, Pratapgarh, Baran and parts of Sirohi.

Summer season is suitable for short duration (60-65 days) varieties of greengram. Hence, the varieties such as IPM 02-03, Sikha (IPM-410-3), Virat (IPM-205-7) and MH-1142 were introduced. These varieties due to its short duration matches well in the existing cropping rotations as catch crops. The output of the introduction generated substantial income more to small and marginal farmers. The profits can be further enhanced through primary and secondary processing and value addition to the grains of greengram.

Adding one more crop in the rotation of two crops has been a successful strategy in enhancing the cropping intensity to 300% from existing 200%. It also provided additional income offsetting the risks associated with kharif cultivation. The new crop rotations of soybean-mustard-greengram and soybean-coriander-greengram, exemplify how innovative agricultural practices can transform the farming systems, leading to more sustainable and resilient agricultural systems. Continued promotion and support for such innovative practices by KVKs and other stakeholders can empower farmers to achieve higher productivity with economic stability and environmental sustainability.



Fig. 29 Mr. Nathu Lal Kumhar in his kharif greengram field at Madhopura village, Ajmer

C. Adoption and promotion of farmer-to-farmer extension

Farmer-to-Farmer Extension (FFE) in India where ratio of extension workers to farmers' is very high is widely acknowledged as a highly effective approach (Meena *et al.*, 2016). The FFE models offer a wide-reaching alternative in supporting agricultural innovation (Ssemakula and Mutimba 2011; Wellard *et al.*, 2013) and it is a complementary approach which involves farmers' sharing knowledge on agricultural innovations within their communities (Lukuyu *et al.*, 2012). KVKs have embraced FFE by expanding their reach and strengthening community accountability. KVKs inculcated the close relationships with farmers' through CFLDs, organizing extension activities and participatory seed production. Farmers' participation is ensured at every stage from decision-making to implementation. This approach ensures that farmers not only receive information but actively participate in shaping and implementing agricultural practices that suit their local conditions.

During 2016-2022, 10 improved varieties viz., GM-4, MH-1142, MH-421, Shikha, Virat, GM-5, GM-6, IPM 2-14, GM-7, and IPM-02-3 were introduced (Table-9). These are preferred by farmers' over local varieties. The FFE helped 4,211 farmers to adopt their varieties across 15 districts, covering a total area of 6,165 ha (Table-9). This widespread adoption indicates farmers' preference for these improved varieties,

Table-9 Area expansion through farmer to farmer extension

S.No.	Districts/KVKs	Improved varieties	Villages covered	Area (in ha)
1	Barmer-I	MH-1142, MH-421, GM-4	Punjasar, Bhiyar, Zaydu, Anti	120
2	Jodhpur-I	GM-4, Virat, MH-421,	Bendo ka bera, Kalimali, Dayakor, Bawadi	325
3	Hanumangarh-I	MH-421	Masidawali, Dhadan, Bolawali	500
4	Hanumangarh-II	MH-421, MH-1142	Bhagwan, Ramsara, Phephana and 25 NTR	270
5	Sriganganagar	MH-1142, MH-421	Kharla and Manaksar village	120
6	Churu	MH-421	Hudera, Devipura, Bayla	175
7	Nagaur-I	MH-421, GM-6, GM-7	Dhehari, Matasukh, Roon, Ren, Deshwal, Amarpura, Khajwana, Rol	1850
8	Sirohi	IPM-410-3, Virat, GM-4, GAM-5	Jhadoli Veer, Uthman, Fachriya, Madani, Dhanta, Tokra, Angor	170
9	Sikar	MH-421	Chchivad, Bagroda, Gangiyasar, Alafsar, Kashwali, Bagiri, Khoru, Harsawa	120
10	Jaipur-I	MH-421, MH- 1142	Dhamana, Lordi, Thali, Mokhampura, Akhepura and Gaduda	850
11	Jhunjunu	MH-421	Varispura, Luttoo, Raghunathpura	150
12	Tonk	IPM 02-3	Lava, Malpura	200
13	Alwar	Shikha, MH-421, MH-1142	Kishangarh Bas, Raipur Mewan, Khilora	297
14	Bhilwara-I	MH 421	Rupaheli	600
15	Rajsamand	Virat, GAM-5	Lasaria, Jhutra, Lapsia	200
16	Baran	IPM 2-3, MH- 1142	Garda, Sadafal, Bhawargarh	218



underscoring the successful implementation of CFLDs. These examples illustrate how seed exchange has facilitated the spread of improved greengram varieties, demonstrating their popularity and successful integration into local farming practices. Documenting numerous cases of successful farmer-to-farmer seed exchanges over time will further highlight its importance and impact.



Fig. 30 Group discussion with the partner farmers at Raipur, Pali

Some successful cases demonstrating farmer-to-farmer seed exchange and the favorable response of improved varieties of greengram are given as under:

Case-I: FFE of GM-7 variety of greengram at Raipur, Pali

A group discussion was conducted at KVK-Pali-II on June 24, 2024 with farmers. The farmers' provided valuable feedback on the newly introduced GM-7 variety. Some of the reflections and positive experiences shared by the farmers are given below:

- Farmers were highly satisfied with the GM-7 variety due to its resistance to diseases for which the local varieties were susceptible.
- The bold seed and its shining colour attracted the farmers to replicate this variety in next season also.
- The farmer-to-farmer extension was emphasized, with one of farmers' Mr. Teja Ram sold 9q of GM-7 seeds to fellow farmers of same village and nearby villages during 2022-23, covering an area of 50 ha. The variety disseminated up to 25 km from the Raipur village (Fig. 32).
- The farmers also observed about the yield that may still be harnessed beyond 9 q/ha in rainfed conditions of Pali-II.
- Some of the farmers with the help of KVK, Pali-II are exploring introducing GM-7 under assured water supply conditions during the summer season to exploit its potential.



Local

Private company seed

GM-7

Fig. 31 Comparison of 'GM-7' variety pod with local/private company variety

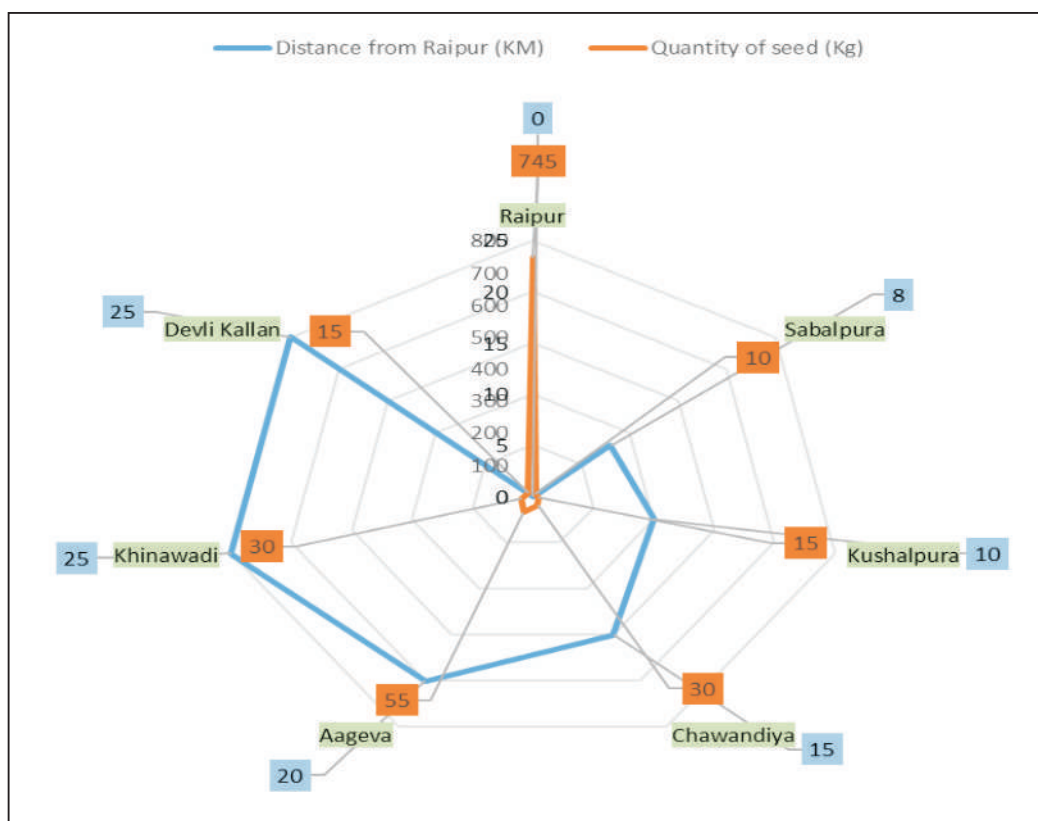


Fig. 32 Farmer to farmer extension of variety 'GM-7' in Pali, Rajasthan



Case-II: FFE of 'MH-1142' greengram at Madhopura, Ajmer, Rajasthan.

Shri Nathu Lal Kumhar, a partner farmer from Madhopura village located 60 km from Ajmer district, has demonstrated impressive productivity of greengram. In 2022, he cultivated MH-1142 variety on 3.5 ha which yielded 50q seed (14.28 q/ha). The KVK procured 17 q from the farmer while the remaining 33 q was sold to the neighboring farmers. Total area of 183.33 ha was covered with seed produced by Shri Nathu Lal. During Kharif 2023, he expanded his cultivation to 16 ha and produced 192 q of seed. KVK, Ajmer procured 80q under the seed hub initiative. Shri Nathu Lal sold the remaining 112q seed to 58 farmers across 17 villages which is likely to cover an area of 622.22 ha in kharif 2024 (Fig. 34). In addition to his village, the seed has been disseminated up to 225 km from the Madhopura. Shri Nathu Lal has also meticulously maintained the production and seed transactions details, following the advise of KVK. After witnessing the success of GM-7 in jurisdiction of Pali-II, he has planned to introduce this variety in his field during kharif 2024. He has been cultivating both local varieties as well those of public and private sectors.



Fig. 33 'MH-1142' greengram at Madhopura, Ajmer, Rajasthan

On-farm experiences demonstrate that FFE approach holds promise as a complementary method to public extension services for disseminating information about advanced agricultural technologies, including improved seeds. This cost-effective approach effectively engages a broader farming community by empowering selected local farmers as leaders of change within their own communities. These farmers are trusted owing to their shared cultural background, local language proficiency, innovative, risk taking, experimenting nature, strong information seeking behavior, and role-model status. They have strong technological backup with KVKs. Hence, this grassroot approach fosters knowledge exchange, with farmers' visiting each other's farms to learn and share insights. Despite challenges related to scalability and sustainability the FFE approach holds significant potential to address the extension needs of farmers', particularly in disadvantaged regions where reach of public sector extension systems is limited. The effectiveness of the approach is dependent upon strong technological support and supportive policy frameworks (Meena *et al.*, 2016).

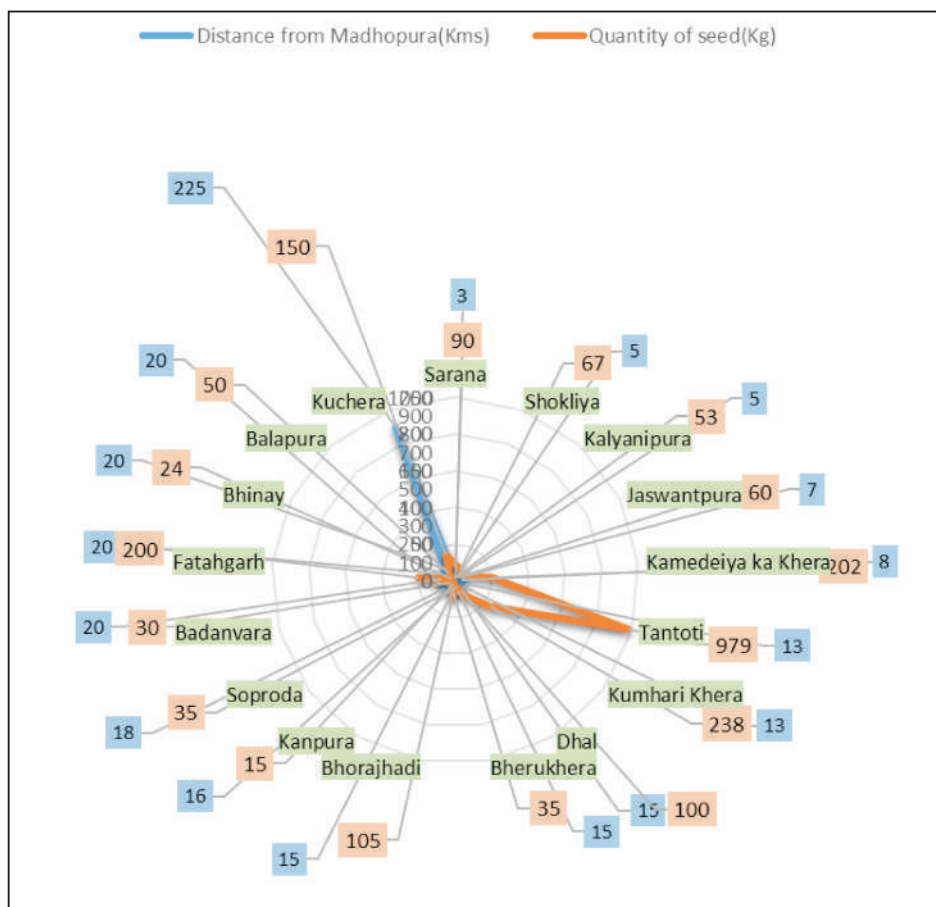


Fig. 34 Farmer to farmer extension of variety 'MH-1142' in Ajmer, Rajasthan

D. Focus on improved agronomic practices

The CFLDs as a carrier of improved PoP, helped empowering farmers in Rajasthan to adopt improved agronomic practices of greengram. The improved PoP increased productivity and fetched higher returns to farmers. The knowledge gained through CFLDs has facilitated the farmers to perceive and adopt new technologies and practices, leading to an overall improvement in their livelihoods. The key practices promoted by KVKs are presented below:

Soil test-based fertilizer application: Despite the challenges such as limited availability of soil testing facilities and lack of awareness, CFLDs promoted the soil test-based fertilizer application. Farmers are encouraged to apply nutrients according to soil testing reports (Soil Health Cards) and following Integrated Nutrient Management (INM) practices. The recommended doses of fertilizers (15:40:00 NPK) along with deficient micro-nutrients like zinc sulphate @25kg/ha were also applied.

High yielding and climate resilient varieties: Farmers were provided with short-duration, high-yielding, and drought resistant greengram varieties developed by State Agricultural Universities (SAUs) and ICAR institutes. Awareness programs and training sessions are also conducted to educate the farmers about the importance and benefits of using these improved varieties.



Seed treatment and plant protection measures: Awareness programs and training sessions also focus on seed treatment and plant protection measures. This ensures better crop health and reduced losses due to pests and diseases.

Seeding techniques: Farmers are shown the impact of line sowing in the recommended planting geometry and maintained optimum plant population in unit area which leads to uniform crop stands and better growth and development of plants leading to higher productivity.

Weed management: Before CFLDs, manual weeding was common, but now farmers' use recommended weedicides and inter-culturing techniques. Pre-emergence application of Pendimethalin 30EC@1.0 kg a.i./ha and the use of Imazethapyr @50g a.i./ha have become standard practices.

Harvesting: Synchronized maturity varieties are introduced, allowing for one-time manual harvesting. This reduces labor costs and ensures uniform grain quality.

Introduction of tools/machines: The synchronous maturity of the improved varieties of greengram has helped reduce costs and enhance productivity through mechanized harvesting. The manual weeding has been replaced by weeder as post effect of CFLDs. Machines are also introduced for harvesting of greengram in plain area mostly by progressive farmers.



Fig. 35 Harvest produce of 'GAM-5' greengram at Sirohi district

The improved agronomic practices proved beneficial to farmers' for obtaining better profits and sustainable farming systems. Success of CFLDs underscores the importance of continuous education, resource provision, and support from agricultural institutions to enhance the productivity and sustainability of farming communities.



8. Way forward

The household consumption demand for pulses has been increasing faster than other food commodities with changing economies. The working group on demand and supply of agricultural produce and inputs of NITI Aayog in 2024 projected the demand of foodgrains at 402 and 415-437 million tons by 2047-48 under BAU and HIG scenarios, respectively. The growth in demand for pulses and nutri-cereals has been projected higher than rice and wheat. The working group estimated 49 to 57 million tons demand of pulses in 2047-48 under different income growth scenarios. In Rajasthan, the opportunities for area expansion still exist with some alternative systems cropping in. Besides, guaranteed yield reservoir with the existing technologies also provides for a huge potential to the state to contribute significantly in augmenting the pulses production in future. Greengram, mothbean and chickpea are the major pulse crops of Rajasthan. The soil and climatic conditions in the state are very congenial for the cultivation of these pulses, among others (Balai *et al.*, 2021). The monetary advantages are also in the favour of greengram and gram in the arid and semi-arid zones of Rajasthan (Sharma and Bhusan, 2019). Nagaur, Pali, Jodhpur, Jalore, Ajmer, Jaipur, and Tonk are dominant pulse producing districts of Rajasthan (Sharma *et al.*, 2017). The growth pattern of pulses has been varying during the different periods post 2000. During the decadal period of 2000-2010, a positive growth of 7.2 and 5.8% was observed in area and production, respectively but productivity growth decelerated at -1.3% (Rani *et al.*, 2023). The high instability index was noticed for production and productivity and medium for area during the same period. The area and production increased at 12.6% and 13.6%, respectively during 2010-2020, almost double of previous decade. There happened a turnaround in the productivity with positive growth at 0.8% per annum during 2010-20. Amongst various pulses area, production and productivity of greengram grew at the fastest rate of 7.4, 13.7, and 5.1% during 2000-2020. The instability of area was medium but high for production and productivity of greengram. The period of 2010-2020 has been promising for greengram in Rajasthan with better growth and low instability indices for area, production, and productivity. Amongst the various factors that played a catalytic role for this positive pathway of greengram growth include the technological interventions under NFSM such as quality seeds of new varieties and critical inputs, CFLDs and expansion of breeder seed production at ICAR institutes and SAUs.

The CFLDs have offered unique experience of minimum guaranteed yield enhancement, effect of quality seed and new varieties and critical inputs along with awareness amongst the farmers which pushed the farmer-to-farmer spread of new variety seeds. It also facilitated evidenced based advocacy for some modifications and augmentation in policies and programmes for enhancing greengram production in Rajasthan. Some of the key policy derivatives which have the potential to augment the greengram production in Rajasthan are discussed in following para:



The districts of Rajasthan that cultivate greengram have been categorized based on their median guaranteed yield augmentation and the variations from the median.

A. Districts with high guaranteed yield: This category includes six districts: Barmer, Hanumangarh, Churu, Jalore, Pali, and Karauli. In these districts the yield gaps between CFLDs and FPs were the largest. Hence, adoption of improved package of practice of greengram can guarantee the highest yields of greengram.

B. Districts with medium guaranteed yield: Fourteen districts fall under this category: Sriganganagar, Bikaner, Jaisalmer, Sikar, Sirohi, Jaipur, Ajmer, Tonk, Dholpur, Sawai Madhopur, Bhilwara, Rajsamand, Baran, and Bundi. In these districts, the yield gaps between CFLDs and FPs were moderate, hence adoption of improved package of practices can boost the yield moderately with assured medium gain to farmers.

C. Districts with low guaranteed yield: This category comprises five districts: Jodhpur, Nagaur, Jhunjhunu, Alwar, and Bharatpur. In these districts, the farmers yields are already close to the highest yields obtained in CFLDs reflecting very low yield gap. Under these circumstances, adoption of improved package of practices (POPs) may yield marginal gain to farmers.

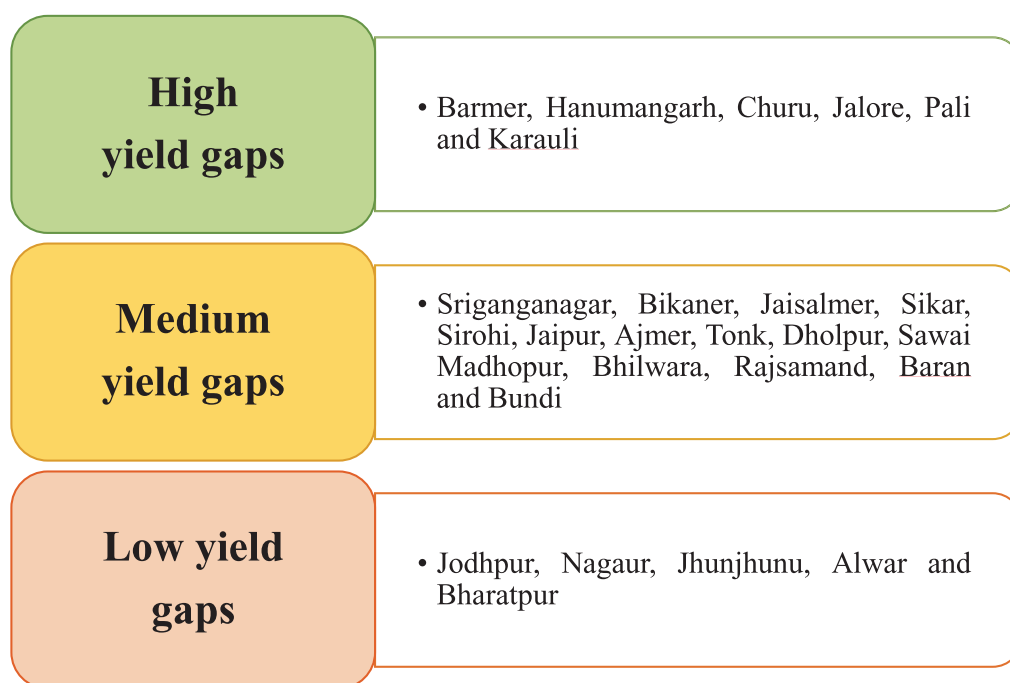


Fig. 36 Classification of districts based on yield gaps

Bridging the yield gaps require a comprehensive short-term action plan, medium term strategy and long-term vision with the defined role and responsibilities and key deliverables for research, extension and development institutions in the districts and states. A targeted and concentrated approach of extension in high spread and low productivity districts can lead to harvest the maximum benefit in shortest period. In



Rajasthan, Nagaur, Jodhpur and Pali districts account for about 50% of area of greengram. These districts need to be prioritized for all interventions in greengram. The saturation approach of villages with modern technologies can be adopted to achieve zero adoption gap in the villages where pulses cover more than 50% of gross cropped area. Such villages need to be mapped and a mission mode strategy with clear deliverables could be put in place for seed, fertilizers and biofertilizers, plant protection chemicals and lifesaving irrigation. This will help absorbing productivity shocks of the farmers. To avoid price shocks, the implementation of MSP in these villages with additional procurement center by National Agricultural Cooperative Marketing Federation (NAFED) or another state-owned agency could be put in place with at least 25% procurement of the particular village. This will help sucking the surplus produce and stabilize the market prices. Once market prices start ruling above MSP, the procurement by agencies may be stopped. In order to have a sustainable model of pulses production, the alternate model of production, aggregation and marketing is the long-term vision with the active involvement of Farmers Producer Organizations (FPOs) and Farmer Producer Companies (FPCs) and processing associations like pulses processors with pre-defined price for purchase from producers by the produce owners. The research endeavor should be on developing varieties which can sustain the moisture stress along with salinity and yield better with low input usage. The public extension should involve both farmers and private players to deepen the reach of technologies and other know-how to the farmers in unreached areas.

1. Availability and access to quality seeds

Both availability and affordability of quality seeds of pulses are challenge in Rajasthan especially high volume of seeds requiring pulse crops. Seed is the carrier of technology. The potential of a quality seed is complimented by applied agricultural inputs alike of nutrients, water, plant protection chemicals. However, deficiency of seeds has often been reported both in quantity and quality and farmers use to run from pillar to post for the want of quality seeds from a reliable source. The present variety development and putting the new varieties into seed chain has some disconnect. While breeder develops a variety, he or she has no accountability to produce adequate amount of breeder seeds for further multiplication. The breeder seed indenting process is also faulty. The seed agencies multiplying the breeder seed into foundation and then to certified grade-I and II, often look their business perspectives. The inclusion of new varieties is often discouraged as they have to make extra effort amongst farmers for liquidation of stock of new varieties as compared to well settled varieties accepted by the farmers. The seed system needs reorientation. Only those varieties should be notified of which breeder or institution guarantee adequate breeder seeds production. The seed multiplying agencies should include at least 25% of breeder seed indent of new varieties every alternate year. The alternate methods of seed production such as seed-hubs and other participatory mode should be strengthened with adequate buy-back and distribution networking. The KVKs of Rajasthan in major pulses producing districts have already gathered adequate experience of seed-hubs of pulses to make them well-placed for facilitating production and distribution of high-quality seeds in collaboration with farmers.



2. Targeting low-hanging fruits in potential regions

Technological breakthrough is required in pulses for exploring current fallows, water and salinity stressed soil and water conditions in a vast tract of Rajasthan and similar ecologies elsewhere. Wherever, the scope of area expansion under pulses has dried up, the productivity augmentation required to be targeted. High Yielding Varieties (HYVs), hybrids and stress tolerant varieties could be developed for the challenged ecologies of Rajasthan. The huge yield reservoir of over 25% in majority of the pulses including greengram should be targeted as 'low hanging fruit' in the state. Besides, the low-cost technologies need to be promoted along with capacity building of the farmers and farm women.

3. Complementing public extension system with alternate extension models

While frontline and field public extension system are carrying out their activities in their catchments, their reach is often constrained with multiple factors including resource and time constraints. The alternate agricultural extension system such as farmer-to-farmer and private-farmers and public-private model need to be developed and utilized wherever possible and appropriate to enhance the reach of extension services. A policy guideline for ensuring quality, accountability and minimizing the conflict of interest is required for all the stakeholders along with credit sharing in such models. Some of the experiences in Rajasthan about farmer to farmers extension of greengram high yielding variety seeds can be replicated with suitable modifications in other ecologies and for different pulses.

4. Utilizing time space between two crops for short season greengram

The assured irrigation and highly productive regions under rice-wheat cropping system of Punjab, Haryana, Uttar Pradesh (UP) and Bihar and maize-potato cropping in western UP have been a bastion of 60-90 days short duration pulses and oilseeds in summer season due to policy interface for diversification. In a quest to find out a suitable and attractive alternative of kharif season greengram which is often constrained with high rainfall, weed infestation, high incidence of insects and pests leading to low productivity and sometimes crop failure, selected districts in Rajasthan such as Sawai Madhopur, Rajsamand, Dungarpur, Baran, and Pratapgarh have been experimented with introduction of three greengram varieties 'IPM-02-04', 'GAM-5', and 'MH-1142' in summer season during 2016-2022. The results have been very promising at an average yield of 906 kg/ha. This intervention has increased the cropping intensity from 200 to 300% in the existing system. The additional net return works out to USD 5.22/day assuming cost of production at Rs. 57.9/kg and MSP at Rs. 85.58/kg of greengram during marketing year 2022-23. This return is adequate to drive out a household from acute poverty. To sustain such new and potential interventions, adequate institutional mechanism of marketing and value addition of the new produce needs to be put in place in these districts.



5. Vertical diversification in greengram and other pulses

The projections of 49-57 million tons demand of pulses in 2047-48 includes raw consumption as dal as well as various other processed products such papd, besan, namkeen, several bakeries and processed ready to cook products. While various Self-Help Groups (SHGs) and few big corporates are working on production of value-added products of pulses, a systematic chain of FPOs of pulses especially greengram needs to be developed with their integration with pulses processing units. A special drive for developing greengram value chain in Rajasthan linking the FPOs, FPCs and SHGs can help sustaining the efforts by the government and the farmers for enhancing the pulses production in the state.

In the centenary year of country's independence, we have to produce 1.8 to 2.1 times more pulses than what has been produced in 2022-23. This is a gigantic task given the challenges in agriculture which are much formidable than the past. The stress-ridden agriculture will be more stressed in 2047 for several reasons. The impacts of climate change are a reality and proven with major shift in crops and cropping pattern already projected. The biotic stresses are becoming even serious and sharper with many new pest complexes developing and shifting from traditional crops to non-traditional crops and areas. The recent shift in fall army worm from maize to other kharif crops, rust, aphid and collar rot from groundnut to cotton, orobanche from mustard to cumin, etc., are some classical examples of changing and shifting biotic stresses. The nutrient deficiency and salt problems in arid ecosystem is already a common and rampant problem. Under these escalating stresses, the pulses production has to be more than doubled in 2047. In India, Rajasthan offers the huge opportunity for augmenting the national pulses production given the scope for area expansion and the guaranteed yield reservoir available with existing technologies.

The agricultural land scape in Rajasthan has been changing with more and more areas getting under over-exploited groundwater zone on one hand and some chronically water-stressed areas are turning green with availability of surface water for irrigation due to new irrigation projects and few more are in the offing. However, there are over-use of water in these areas from some crops like groundnut and cotton. The matrix and design of cropping needs to be changed in entirety under various agro-ecological zones according to farm resource endowments. The policy prescriptions and water governance need to enforced with vigour but under adequate advocacy and dialogues with the users. The high-water demanding crops needs to be diversified towards low water demanding pulses with infusion of better technologies and policy prescriptions to address the various issues and opportunities from plough to plate.



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