

Performance of FLD on climate resilient practices in green gram in Jhunjhunu district of Rajasthan

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Summary

Climate variability and erratic rainfall patterns pose significant challenges to pulse production in semi-arid and rainfed ecosystems. This study was conducted from 2020 to 2024 to assess the effect of climate-resilient agricultural practices (CRPs) on the yield, economics, and extension performance of moongbean (*Vigna radiata* L.) under field conditions. Frontline demonstrations (FLDs) implementing improved management practices—such as the use of short-duration drought-tolerant varieties, integrated nutrient management and moisture conservation with supplemental irrigation were compared against the farmers' traditional practices (FP) across multiple years and varying rainfall regimes. The results indicated a consistent enhancement in both yield and profitability under climate-resilient practices. The average yield across five years was 7.59 q ha⁻¹ under demonstrations compared to 6.42 q ha⁻¹ under FP, reflecting a mean yield advantage of 18.2%. Correspondingly, the gross return and net return averaged Rs. 62,264 ha⁻¹ and Rs. 37,836 ha⁻¹, respectively, which were markedly higher than Rs. 52,610 ha⁻¹ and Rs. 29,170 ha⁻¹ recorded under FP. Despite a slightly higher cost of cultivation, the benefit–cost (B:C) ratio was more favorable in the demonstration plots (2.46) than under FP (2.13), confirming the economic feasibility and resilience of CRPs. Extension analysis revealed notable improvements in technology dissemination and adoption. The technology gap ranged from 1.8 to 5.4 q ha⁻¹, while the extension gap varied between 1.04 and 1.60 q ha⁻¹ across years. The technology index declined substantially from 44.83% in 2023 to 15.00% in 2024, signifying enhanced field-level adoption and improved efficiency of the demonstrated technologies. Regression analysis between rainfall and yield revealed a weak positive correlation (0.049 for CRPs; 0.040 for FP), indicating that rainfall alone explained less than 5% of yield variability. Overall, the study concludes that adoption of climate-resilient technologies significantly enhances productivity, profitability, and technology adoption in moongbean cultivation under rainfed conditions. These practices not only stabilize yields but also improve resource-use efficiency, making them crucial for climate adaptation, income security, and sustainable pulse production in vulnerable agro-ecological regions.

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Introduction

India is the world's largest producer and consumer of pulses, with moongbean (*Vigna radiata*), commonly known as green gram, being a critical component of this sector. It plays a vital role not only in ensuring nutritional security due to its high protein content (24–26%) but also in sustaining soil fertility through its nitrogen-fixing ability. Among Indian states, Rajasthan dominates moongbean cultivation, accounting for approximately 70% of the total area under production (Meena 2023). Within Rajasthan, the Jhunjhunu district in the Shekhawati region is known for its semi-arid climate and is one of the prominent zones for moongbean farming. Jhunjhunu is situated in the transitional belt between arid and semi-arid zones of Rajasthan, characterized by erratic and low rainfall (typically below 500 mm/year), high temperature, and sandy loam soils. These

conditions pose substantial challenges to conventional farming. However, moongbean's short duration and drought-resilient traits make it a suitable crop for this region. Despite this, climatic uncertainties, particularly in kharif (monsoon) seasons, have often led to suboptimal yields (Joshi et al. 2009).

To address the climatic vulnerability, farmers and researchers have turned to drought-tolerant agronomic practices. These include the selection of drought-resistant varieties, conservation tillage, use of organic soil amendments (e.g., vermiwash, compost), micro-irrigation, and biofertilizer application. For instance, recent studies in western Rajasthan demonstrated that integrated drought management—such as mulching, line sowing with wider spacing, and seed priming with *rhizobium* cultures—can significantly improve plant stand, moisture retention, and grain yield under water-limited conditions (Kumawat, 2019).

Moreover, the introduction of short-duration, climate-resilient moongbean varieties such as MH-421 and MH-1142 have gained traction in Jhunjhunu and neighbouring districts. These cultivars not only escape

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terminal drought due to their early maturity but also exhibit moderate resistance to yellow mosaic virus (YMV), a major biotic stress in the region (Manga et al. 2015).

The adoption of drought-tolerant practices in moongbean cultivation has implications beyond crop production. For smallholder farmers in Jhunjhunu, whose livelihoods depend on rainfed agriculture, these practices offer a pathway to income stabilization. Empirical demonstrations by Krishi Vigyan Kendras (KVKs) and ICAR institutes have shown that using improved seed and protective irrigation can double yields and improve profitability under similar climatic stress (Meena 2023). Furthermore, the economic sustainability of these practices is enhanced by their low input requirements. For instance, the use of vermiwash, a liquid organic fertilizer, has shown to improve root health and drought endurance without significant financial investment (Meena 2023). While multiple drought mitigation strategies have been evaluated in various agro-climatic zones, there is a scarcity of region-specific studies that quantify the impact of these practices in Jhunjhunu. Given the unique edaphic and climatic conditions of this district, it is crucial to assess the localized effectiveness of these interventions. This study, therefore, seeks to bridge this gap by systematically evaluating the agronomic and economic impacts of drought-tolerant practices in moongbean cultivation in Jhunjhunu district.

Materials and Methods

The study was conducted in the villages (Bharu, Chakwas & Madansar) of Jhunjhunu district, Rajasthan, from 2021 to 2024 with the help of farmer participatory approach under NICRA project. In this study we included 12-25 farmers in each year from the three selected NICRA villages. The region falls under the *Transitional Plain of Inland Drainage* agro-climatic zone of Rajasthan & semi-arid zone of India, with an average annual rainfall of 350 mm, mostly received during monsoon (July–September). The soil is sandy loam with low organic matter content and lower water-holding capacity. Baseline data on greengram productivity, soil fertility,

rainfall, and temperature patterns were recorded for the pre-intervention in every year.

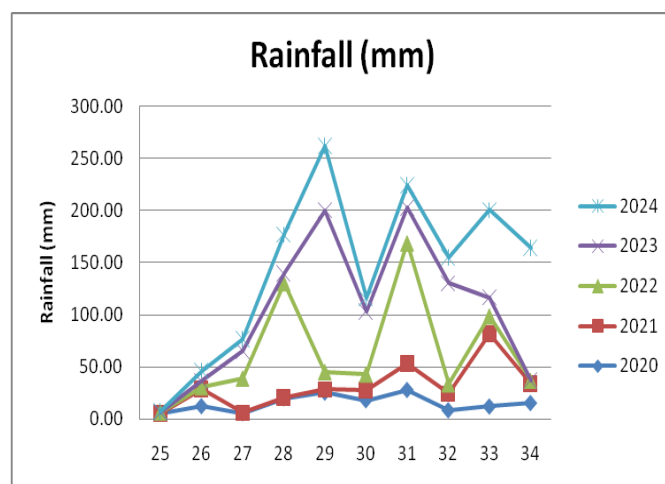


Figure 1. Rainfall pattern during study period over five years

The practices implemented included line sowing, in-situ moisture conservation, drought-tolerant and short duration variety (MH-421 & MH-1142), and integrated nutrient management. Additionally, real-time agro-advisories were provided using ICT tools, ensuring timely interventions in response to climatic aberrations. Demonstration plot size was 0.4 ha. The treatments included: T₁: Climate Resilient Practices & T₂: Farmers Practices. Data on greengram yield and yield attributes, and economic returns were collected and the mean data are presented in Tables.

Results and Discussion

1. Number of Pods per Plant and Number of Seeds per Pod

The data presented in Table 1 revealed the influence of climate-resilient agronomic practices on yield attributes, specifically the number of pods per plant and the number of seeds per pod of moongbean across five consecutive years (2020–2024). Considerable year-to-year variations were observed, likely due to fluctuations in climatic conditions such as rainfall pattern, temperature regime, and soil moisture availability during the reproductive stage.

Table 1. Comparisons of different improved technology and farmer practices

SN	Particular	FLDs technology	Farmers Practices
1	Variety	MH-421 @ MH-1142	Private Company seed
2	Land preparation	Ploughing and harrowing	Ploughing and harrowing
3	Sowing Method	Line sowing	Line sowing
4	Seed rate (kg/ha)	15	18-20
5	Seed treatments	Seed treatment with <i>Trichoderma viride</i> 10 ml per kilogram seed followed by Azotobacter and PSB culture	Nil
6	Fertilizer dose	20:40:00 N:P:K	Nil
7	Irrigation method	Rainfed + supplemental irrigation with sprinkler	Rainfed only
8	Weed management	Use of Pendimethalin @ 1 kg. a.i./ha as pre-emergence and one hand weeding	Use of Pendimethalin @ 1 kg. a.i./ha as pre-emergence
9	Plant protection measure	Thiomethaxom @125 ml/ha for control of white fly and tobacco mosaic resistance variety.	Nil

1.1 Number of Pods per Plant

Across all years, the treatment T_1 consistently produced a higher number of pods per plant compared to T_2 . The number of pods per plant ranged from 9.1 to 12.3 in T_1 and 8.1 to 9.5 in T_2 . The pooled mean indicated that T_1 recorded 11.1 pods per plant, while T_2 had 9.62 pods per plant, suggesting a ~8.7% increase under climate-resilient practice (T_1). These results indicate that resilient agronomic interventions-possibly including moisture conservation and stress-mitigating inputs-contributed to improved pod formation (Kumar et al. 2020; Singh et al. 2022). Similar trends have been reported by (Patel et al. 2021; Meena, 2023), who observed enhanced reproductive efficiency and pod setting in moongbean under integrated climate-resilient management systems. The physiological mechanisms underlying this improvement are attributed to better canopy temperature regulation and improved photosynthates translocation during pod development under adaptive practices (Kumari et al. 2022).

1.2 Number of Seeds per Pod

A parallel trend was observed for the number of seeds per pod. The pooled mean values showed 5.78 seeds per pod in T_1 compared to 5.42 in T_2 , reflecting a consistent advantage of T_1 across all five years. The highest seed count (6.8) was recorded in 2024 under T_1 , which coincided with favorable rainfall distribution. Enhanced seed setting under resilient management may be attributed to better pollination success, reduced

flower drop, and sustained plant vigor under moderate stress environments (Reddy et al. 2021). The findings suggest that implementing climate-resilient practices significantly enhances the reproductive performance of moongbean, as evidenced by the increase in both pods per plant and seeds per pod. This improvement may be attributed to better soil moisture conservation, reduced heat stress effects, and improved nutrient uptake under adaptive management systems. These results align with previous research emphasizing the importance of climate-smart agronomy in sustaining legume productivity under variable climatic scenarios (Kumar et al. 2020, Meena 2023; Singh et al. 2022b).

2 Yield Improvement

Across the five-year period (Table 2), moongbean yield in the demonstration plots ranged from 6.62 to 10.20 q ha⁻¹, with an overall average of 7.59 q ha⁻¹, whereas the farmers' practice recorded yields between 5.49 and 8.60 q ha⁻¹, averaging 6.42 q ha⁻¹. This reflects a mean yield advantage of 18.2% under climate-resilient practices. The highest yield (10.20 q ha⁻¹) was observed in 2024, attributed to favorable rainfall distribution and improved soil moisture conservation measures adopted that year. These findings corroborate earlier reports indicating that integrated soil and water management, short-duration drought-tolerant varieties significantly enhance legume productivity under variable climatic conditions (Kumar et al. 2021; Singh et al. 2022b).

Table 2. Effect of Climate-resilient practices on number of pods per plant and number of seeds per plant of moongbean.

Particulars	Number of pods plant ⁻¹						Number of seeds pod ⁻¹					
	2020	2021	2022	2023	2024	Pooled	2020	2021	2022	2023	2024	Pooled
T_1	10.9	9.1	11.3	11.8	12.3	11.1	5.6	5.2	5.1	6.2	6.8	5.78
T_2	9.4	8.1	9.8	10.2	10.6	9.62	5.1	5.0	5.1	5.8	6.1	5.42

3 Economics

The economic indicators-Gross Return, Cost of Cultivation (CoC), Net Return, and Benefit-Cost (B:C) ratio-further confirm the advantage of resilient practices (Table 2). The average gross return from demonstration plots was Rs. 62,264 ha⁻¹, compared to Rs. 52,610 ha⁻¹ under FP, showing an enhancement of approximately 18.3%. Although the CoC was slightly higher in demonstrations (Rs. 24,438 ha⁻¹) due to inputs like improved seed and soil amendments, the average net return remained substantially higher (Rs. 37,836 ha⁻¹) compared to FP (Rs. 29,170 ha⁻¹). The benefit-cost ratio (B:C) also improved from 2.13 under FP to 2.46 under demonstration, indicating higher profitability and economic resilience. Over the five-year span, both yield and economic parameters showed an upward trend, particularly in 2023 and 2024. This improvement suggests that cumulative soil health restoration and better adaptation strategies enhanced the sustainability of moongbean cultivation under climate variability. The steady yield and profitability gains underscore that adoption of climate-resilient technologies offers a viable pathway for improving pulse productivity and farmer livelihood security in semi-arid regions.

4 Technology and Extension Gaps

The technology gap, defined as the difference between potential yield and demonstration yield, fluctuated between 1.8 and 5.4 q ha⁻¹, depending on climatic conditions and management practices. The lowest technology gap (1.8 q ha⁻¹) was recorded in 2024, corresponding with better rainfall distribution and higher adoption of adaptive measures such as early sowing, improved drainage, and use of drought-tolerant varieties (Table 3). Conversely, the highest gap (5.4 q ha⁻¹) in 2023 indicates that even with high rainfall, suboptimal moisture management and pest incidence may have constrained yield realization. The extension gap, representing the difference between demonstration and farmers' practice yields, ranged from 1.04 to 1.60 q ha⁻¹, reflecting the performance gap between improved and traditional practices. The consistent positive extension gap throughout the years demonstrates the superior performance of climate-resilient technologies and highlights the need for wider dissemination through structured extension programs. Similar trends were reported by Singh et al. (2022) and Chaudhary et al. (2023), who found that integrated field demonstrations effectively narrow the knowledge-practice gap in pulse crops.

5. Technology Index

The technology index, which measures the feasibility and effectiveness of improved technologies under field conditions, ranged from 44.83% in 2023 to 15.00% in 2024. A lower technology index indicates higher technological feasibility and better adoption potential. Thus, the sharp decline in 2024 reflects improved management efficiency and better adaptation of farmers to CRPs. The overall trend reveals that continuous capacity building, combined with favorable rainfall and improved resource management, enhances the practical applicability of climate-smart technologies (Rathore et al. 2020b; Yadav et al. 2023).

6. Relationship of yield with rainfall

These equations indicate a positive but weak correlation between rainfall and yield in both cases. Although yield tends to increase slightly with higher rainfall, the very low R^2 values (<0.05) suggest that rainfall alone accounts for less than 5% of the variation in yield (Table

outcomes. Under climate-resilient management, the slope (0.002) was marginally higher than that of the farmers' practice (0.001), reflecting a somewhat better responsiveness of yield to rainfall. This can be attributed to the adoption of moisture-conserving and adaptive agronomic practices such as mulching, use of short-duration drought-tolerant varieties, and timely sowing, which enhanced the efficiency of rainfall use. The weak overall correlation indicates that rainfall variability alone did not determine productivity. Instead, management intensity and resource optimization played a pivotal role in stabilizing yields. These findings align with reports by Kumar et al. (2021) and Rathore et al. (2020), who observed that integrated soil-water-plant management systems can decouple yield performance from rainfall dependency, improve resilience under erratic climatic conditions. Thus, while rainfall remains a crucial input, the superior yield performance under climate-resilient practices suggests that adaptive agronomic measures

Table 3. Effect of climate-resilient practices on yield and economics of the moongbean crop

S. No.	2020		2021		2022		2023		2024		AVERAGE	
	Demon	FP	Demon	FP	Demon	FP	Demon	FP	Demon	FP	Demon	FP
Yield (q/ha)	8.02	6.74	7.10	6.05	7.39	6.35	6.62	5.49	10.20	8.60	7.59	6.42
Gross Return (Rs)	57712	48537	51652	44135	57330	49224	56653	46983	87975	74175	62264	52610
CoC (Rs)	21050	20230	21260	20425	22780	21750	25700	24900	36400	37600	24438	23441
Net Return (Rs)	36662	28307	30392	23710	34550	27474	30953	22083	51575	36575	37836	29170
B:C ratio	2.74	2.40	2.43	2.16	2.52	2.26	2.20	1.88	2.41	1.97	2.46	2.13

4, Figure 2(a) and 2(b). This implies that factors other than rainfall—such as crop management, and varietal performance had a more dominant influence on yield

effectively buffer the crop against climatic fluctuations, leading to higher and more stable yields over time.

Table 4. Effect of climate-resilient practices on extension indices of moongbean crop

Years	Rainfall (mm)	No of farmers	Area (ha)	Potential yield (q/ha)	Technology gap (q/ha)	Extension Gap (q/ha)	Technology Index (%)
2020	151.70	12	4.8	12	3.98	1.28	33.17
2021	157.70	15	3.8	12	4.9	1.05	40.83
2022	320.88	15	3.8	12	4.6	1.04	38.42
2023	406.30	25	10	12	5.4	1.13	44.83
2024	389.60	25	10	12	1.8	1.60	15.00

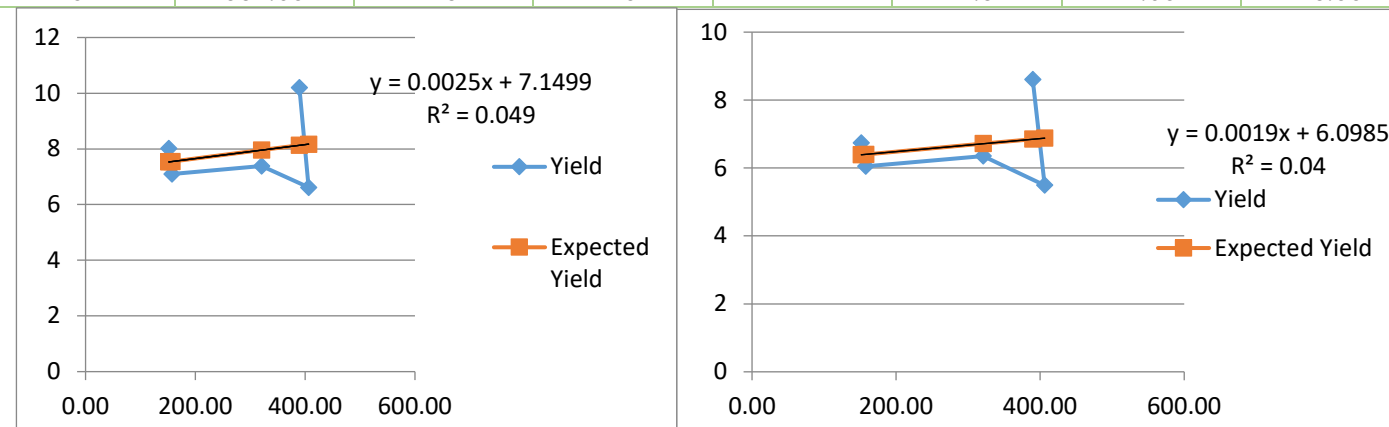


Figure 2(a) and 2(b). Regression between rainfall and yield of green gram

Conclusion

The study highlights the effectiveness of drought-tolerant agricultural practices in improving moongbean productivity under water-limited conditions in Jhunjhunu district, Rajasthan. The adoption of these climate-resilient practices can ensure stable moongbean production, enhance farmer income, and promote water conservation in drought-prone regions. The five-year study (2020–2024) clearly demonstrates that the adoption of climate-resilient agricultural practices (CRPs) significantly improved the yield, profitability, and extension performance of the moongbean (*Vigna radiata* L.) crop under varying climatic conditions. Extension indicators revealed a progressive reduction in technology and extension gaps, along with a marked decline in the technology index (from 44.83% in 2023 to 15.00% in 2024)—reflecting enhanced farmer adoption, knowledge dissemination, and field-level adoption of CRPs. The steady increase in the number of participating farmers and area under demonstrations further validates the growing acceptance and scalability of these interventions.

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