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Impact Assessment of Cluster Frontline Demonstrations on Summer Moong (*Vigna radiata*) Production in Sonipat, Haryana

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ABSTRACT

Background: Pulses are a vital component of India's agricultural landscape, serving as a primary protein source in diets and contributing to soil fertility through nitrogen fixation. However, persistent production deficits, driven by low yields and limited adoption of modern technologies, have hindered self-sufficiency, necessitating imports to meet growing demand.

Methods: This study investigates the transformative impact of cluster frontline demonstrations (CFLDs) on summer moong (*Vigna radiata*) cultivation in Sonipat, Haryana, over the period from 2017 to 2022. Conducted across 350 demonstrations covering 140 hectares in 35 villages, the CFLDs showcased advanced agricultural practices-including high-yielding varieties, optimized nutrient management and integrated pest control-compared against traditional farmer methods.

Result: The results were striking: Demonstration plots achieved an average yield of 7.33 quintals per hectare (q/ha), surpassing the control plots' 5.77 q/ha by 27.26%. Economically, the benefits were even more pronounced, with net returns increasing by 43.4% (Rs. 18,529/ha vs. Rs. 12,924/ha) and the benefit-cost (B: C) ratio improving from 1.83 to 2.14. These gains were consistent across years, with demonstration plots exhibiting lower yield variability (coefficient of variation: 8.5% vs. 10.2%), highlighting the stability and resilience of the interventions even under variable climatic conditions. Farmer feedback was overwhelmingly positive, with 82% of participants expressing intent to adopt the demonstrated technologies, though challenges such as seed availability, input costs and market price fluctuations were noted as barriers. Beyond immediate productivity and profitability gains, the CFLDs fostered greater farmer confidence in modern practices, paving the way for broader technology dissemination. This study underscores the potential of CFLDs as a scalable extension model to address India's pulse deficit, enhance rural livelihoods and promote sustainable agriculture.

Key words: Cluster frontline demonstrations, Economic returns, Technology transfer, Yield enhancement.

INTRODUCTION

Pulses hold a unique and indispensable position in Indian agriculture, underpinning both nutritional security and ecological sustainability. As a rich source of plant-based protein, essential amino acids and micronutrients, pulses like moong (*Vigna radiata*) are dietary staples, particularly for India's vast vegetarian population, which constitutes over 30% of its 1.4 billion people (Shalendra *et al.,* 2013). Agronomically, pulses enhance soil health by fixing atmospheric nitrogen, reducing dependency on chemical fertilizers and supporting crop rotation systems that mitigate soil degradation-a critical advantage in the context of India's intensive farming practices (Meena *et al.,* 2018). Despite their significance, India's pulse production has struggled to keep pace with rising demand. In 2020-21, the country produced 23.01 million tons of pulses-accounting for roughly 25% of global output-yet still imported approximately 3 million tons to bridge the consumption gap (Suryavanshi *et al.,* 2020). Projections suggest that by 2050, demand could reach 39 million tons, driven by population growth, urbanization and shifting dietary preferences toward protein-rich foods (Reddy, 2019). This persistent shortfall stems from multiple challenges: Low productivity (averaging 0.8-1.0 t/ha against a global average of 1.5 t/ha), reliance on outdated farming techniques, limited access to quality seeds and inputs and weak extension systems that fail to bridge the knowledge gap between research and practice (Kumar and Kispotta, 2017).

Summer moong emerges as a strategic crop to address these issues. A short-duration pulse (60-70 days),

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it is cultivated during the pre-monsoon window (March-June), leveraging residual soil moisture from the rabi season and requiring minimal irrigation compared to cereals like rice or wheat. Its adaptability to high temperatures and drought-prone conditions, coupled with its nitrogen-fixing capability, makes it an ideal fit for northern India's rice-wheat cropping systems, where it serves as a low-risk intercrop that enhances both farm income and soil fertility (Singh *et al.,* 2022). Nationally, however, summer moong yields languish at 5-6 q/ha, far below the potential of 10-12 q/ha achievable with improved varieties and management practices (Hiremath and Hilli, 2012). This yield gap reflects systemic barriers: farmers' preference for local, low-yielding varieties; suboptimal use of fertilizers and pest control and inadequate awareness of modern technologies. Bridging this gap requires innovative extension approaches that go beyond traditional methods-such as lectures or pamphlets-which often fail to convince risk-averse smallholders of the tangible benefits of change (Dhaka *et al.,* 2016).

Enter cluster frontline demonstrations (CFLDs), an initiative spearheaded by the Indian Council of Agricultural Research (ICAR) through its network of Krishi Vigyan Kendras (KVKs). Unlike conventional extension, which emphasizes top-down knowledge dissemination, CFLDs adopt a participatory, field-based approach. By establishing demonstration plots in farmers' own fields, CFLDs provide visible, side-by-side comparisons of improved practices against traditional methods, offering concrete evidence of their impact on yields, costs and profits (Sharma *et al.,* 2016). This experiential learning model is particularly effective in rural India, where literacy rates average 65% and farmers rely heavily on observation and peer validation to adopt new practices (Kumar *et al.,* 2020). Since their inception under the National Food Security Mission, CFLDs have targeted pulses to boost production, with summer moong identified as a priority crop due to its economic and ecological potential.

This study evaluates the impact of CFLDs on summer moong production in Sonipat, Haryana, from 2017 to 2022. Located in the Indo-gangetic plains, Sonipat exemplifies northern India's agricultural heartland, characterized by fertile soils, intensive cropping and a predominance of small and marginal farmers (Yadav *et al.,* 2007). Over five years, 350 demonstrations were conducted across 140 hectares, comparing advanced technologies-such as high-yielding varieties, balanced fertilization and pest management-with local practices. The objectives were threefold: to quantify improvements in yield and economic returns, assess technology adoption rates and identify barriers to scaling these interventions. By providing a detailed analysis of these outcomes, this study contributes to the growing body of evidence on CFLDs as a catalyst for agricultural transformation (Verma *et al.,* 2018). The findings hold broader implications for pulse production, rural development and sustainable farming in India, particularly as climate change and market volatility increasingly challenge traditional systems. Therefore, the present study was undertaken with the following objectives: (1) to assess the yield performance of summer moong under CFLDs; (2) to evaluate the economic *via*bility of improved technologies; (3) to analyze technology gaps and adoption barriers in the Sonipat region. While the findings are robust, the study relied primarily on descriptive statistics and lacked region-wide soil profiling and long-term environmental impact analysis. Future research could incorporate remote sensing, long-term monitoring and participatory feedback loops. The interventions not only improved yield and income but also contributed to sustainable farming by promoting low-input, environmentally friendly practices that enhance soil fertility and reduce chemical dependency.

MATERIALS AND METHODS

Study area

Sonipat district, situated in Haryana within the Indo-Gangetic plains (28.99°N, 77.02°E, elevation 224 m), provides an ideal setting for this study. The region experiences a semi-arid subtropical climate, with temperatures soaring above 40°C in summer and dropping to 5°C in winter, alongside an average annual rainfall of 700 mm, predominantly during the July-September monsoon. This climatic profile necessitates supplemental irrigation for summer crops like moong, typically sourced from canals (*e.g.*, the Western Yamuna Canal) and tube wells. The district's soils are alluvial and loamy, with a pH range of 7.5-8.0, good drainage and moderate organic carbon content (0.4-0.6%), making them well-suited for pulse cultivation when nutrient management is optimized. Agriculture dominates Sonipat's economy, supporting over 60% of its 1.5 million population, with small and marginal farmers (holding <2 ha) comprising the majority of cultivators. The rice-wheat system prevails, but summer moong has gained traction as a third crop, sown post-wheat harvest in late March or early April and reaped by June, aligning with the region's cropping calendar without disrupting major seasons (Singh *et al.,* 2022). For this study, 35 villages were strategically selected based on agro-ecological representativeness, farmer willingness and logistical accessibility, covering a total demonstration area of 140 hectares over five years.

Demonstration design and implementation

Between 2017 and 2022, 350 CFLDs were executed across the selected villages, each demonstration spanning 0.4 hectares, totalling 140 hectares. The experimental design employed a paired-plot approach: each demonstration plot was paired with an adjacent control plot of identical size, managed using farmers' traditional practices. This setup ensured that variables such as soil type, microclimate and irrigation access remained constant, isolating the effects of the technological interventions. The summer moong variety MH-421, developed by Punjab Agricultural University,

was chosen for its high yield potential (up to 10 q/ha), early maturity (60-65 days) and resistance to yellow mosaic virus-a prevalent threat in northern India (Singh *et al.,* 2022). Control plots, conversely, relied on local varieties with lower genetic potential and greater disease susceptibility.

Farmer selection was participatory, prioritizing those with representative landholdings (1-2 ha), willingness to adopt new practices and proximity to demonstration sites for community visibility. Pre-season training workshops, led by KVK scientists, covered critical topics: Seed selection and treatment, soil fertility management, weed and pest control and harvesting techniques. These sessions, attended by 20-30 farmers each, were interactive, encouraging questions and hands-on practice. During the growing season, field days and farmer-scientist interactions were organized at key stages (sowing, flowering and harvest), allowing participants and neighbors to observe progress, discuss challenges and build trust in the technologies. This participatory framework not only ensured proper implementation but also amplified the demonstrations' ripple effect across the community (Sharma *et al.,* 2016; Meena *et al.,* 2021).

Technological interventions

The CFLDs introduced a holistic package of improved practices, designed to maximize yield, minimize environmental impact and align with local resources:

- **Variety:** MH-421, selected for its superior agronomic traits and adaptability to Haryana's climate.
- **Seed rate:** Standardized at 25 kg/ha to achieve an optimal plant population of 300,000-350,000 plants/ha, balancing competition and productivity.
- **Seed treatment:** Seeds were treated with Carbendazim (2 g/kg) to combat soil-borne fungal pathogens like *Rhizoctonia* and *Fusarium*, followed by inoculation with *Azotobacter* (150 ml/ha) and phosphate solubilizing bacteria (PSB, 150 ml/ha) to enhance nutrient uptake and root vigor.
- **Fertilizer application:** A basal dose of 20 kg N/ha (*via* urea) and 40 kg P_2O_5/ha (*via* single superphosphate) was applied at sowing, addressing the crop's early nutrient demands and compensating for the region's phosphorus-deficient soils.
- **Weed management:** Pre-emergence application of Pendimethalin 30 EC (3.25 L/ha) controlled broadleaf weeds and grasses, supplemented by one manual weeding at 25-30 days after sowing (DAS) where necessary.
- **Pest management:** Imidacloprid (250 ml/ha) was applied as needed to manage sucking pests like aphids and whiteflies, guided by economic threshold levels to reduce chemical overuse.

Control plots reflected prevailing farmer practices: local varieties (*e.g.*, SML-668 or farmer-saved seed), minimal seed treatment (often none), sporadic fertilizer use (typically 10-15 kg N/ha, rarely phosphorus) and reactive pest control with broad-spectrum insecticides. Both plot types were sown between mid-March and early April, irrigated 2-3 times depending on rainfall and harvested in June, ensuring a synchronized timeline for comparison.

Data collection and analysis

Data collection was meticulous, capturing agronomic, economic and social dimensions. Yield was assessed by harvesting three randomly selected 5 × 5 m quadrats per plot, threshing and drying the grain to 12% moisture content, then extrapolating to q/ha. Economic parameters were derived from detailed cost and revenue records: input costs (seeds, fertilizers, labor, irrigation, pesticides) were logged per plot, while output values reflected market prices, which rose from Rs. 4,500/q in 2017-18 to Rs. 6,000/q in 2021-22 due to demand surges. Key metrics included:

Gross returns (Rs/ha) = Yield (q/ha) × Market price (Rs/q)

Net returns (Rs/ha) = Gross returns - Total cost of cultivation

$$\text{Benefit-cost ratio (B:C)} = \frac{\text{Gross returns}}{\text{Total cost of cultivation}}$$

Technology adoption potential was evaluated using

Technology gap (q/ha) =

Potential yield (10 q/ha for MH-421) - Demonstration yield

Extension gap (q/ha) =

Demonstration yield - Farmers' practice yield

Technology index (%) =

$$\frac{\text{Potential yield - Demonstration yield}}{\text{Potential yield}} \times 100$$

Farmer perceptions were gathered *via* structured interviews (n=350) and focus groups (10 sessions, 8-12 farmers each), probing satisfaction, adoption intent and constraints. Data were analyzed using descriptive statistics (means, percentages), with variability assessed *via* coefficients of variation (CV) and trends tracked annually to identify patterns and anomalies.

RESULTS AND DISCUSSION

Yield performance

The CFLDs significantly enhanced summer moong yields across the study period. Demonstration plots averaged 7.33 q/ha, compared to 5.77 q/ha in control plots-a 27.26% increase (Table 1). This extension gap of 1.56 q/ha reflects the immediate advantage of improved practices, with gains peaking at 32.99% in 2018-19 (a year of optimal rainfall) and dipping to 15.52% in 2019-20 (marked by a heatwave). Year-to-year fluctuations were driven by weather variability-*e.g.*, untimely rains in 2018-19 boosted vegetative growth, while high temperatures in 2019-20 reduced pod setting-but demonstration plots consistently outperformed controls, affirming the robustness of the interventions (Dhaka *et al.,* 2016). The technology gap averaged 2.67 q/ha, indicating that demonstration yields fell short of MH-421's potential (10 q/ha), likely due to suboptimal irrigation or pest pressures not fully addressed by the package (Sandhu

and Dhaliwal, 2016). The technology index of 26.7% suggests that while substantial progress was made, further refinements-such as drip irrigation or advanced biocontrol-could push yields closer to the ceiling (Lalit *et al.,* 2015; Kumar *et al.,* 2020). To further strengthen the credibility of these results, incorporation of detailed statistical analyses such as ANOVA or t-tests is recommended.

Economic analysis

Economically, the CFLDs delivered compelling returns. Although cultivation costs in demonstration plots were higher (Rs. 16,657/ha vs. Rs. 15,298/ha) due to investments in seeds, biofertilizers and pest control, gross returns averaged Rs. 35,186/ha compared to Rs. 28,223/ha in controls. This translated to a 43.4% increase in net returns (Rs. 18,529/ha vs. Rs. 12,924/ha) and a B:C ratio of 2.14 versus 1.83 (Table 2). The economic edge was most pronounced in 2021-22, when high market prices (Rs. 6,000/q) and a demonstration yield of 7.92 q/ha yielded a B:C of 2.89-among the highest recorded for pulses in similar studies (Kumar *et al.,* 2019). Even in lean years like 2019-20, the B: C remained favourable (1.64 vs. 1.57), reflecting the interventions' resilience (Singh *et al.,* 2020). The additional cost of Rs. 1,359/ha was offset by an average net gain of Rs. 5,605/ha, offering a return-on-investment ratio of 4.12:1-a strong incentive for adoption (Suryavanshi *et al.,* 2020).

Variability and trends

Yield trends underscored the progressive impact of CFLDs. Demonstration yields rose from 6.45 q/ha in 2018-19 to 7.92 q/ha in 2021-22, reflecting cumulative learning and refined management, while control yields hovered between 4.85 and 6.20 q/ha with no clear trend. The CV for demonstration yields (8.5%) was lower than for controls (10.2%), indicating greater stability-a critical factor for smallholders facing climatic and market risks (Meena *et al.,* 2018). Economic metrics mirrored this pattern: The B:C ratio in demonstration plots climbed from 1.64 to 2.89, driven by yield gains and price increases, while control plots peaked at 2.27 in 2021-22 (Verma *et al.,* 2018). These trends suggest that sustained exposure to CFLDs could narrow yield and income gaps further over time (Kumar *et al.,* 2020).

Fig 1 illustrates annual yield trends. Demonstration yields begin at 7.80 q/ha in 2017-18, dip to 6.45 q/ha in 2018-19 due to drought stress and climb steadily to 7.92 q/ha by 2021-22. Control yields fluctuate between 4.85 q/ha (2018-19) and 6.20 q/ha (2021-22), showing no consistent improvement. The widening gap highlights the sustained efficacy of improved practices over traditional methods.

Farmers' feedback and technology adoption

Feedback from 350 farmers revealed strong approval of the CFLDs, with 82% intending to adopt the technologies fully or partially. Key drivers included higher yields (cited by 90%), increased profits (85%) and ease of integration into existing systems (70%). However, barriers emerged: 45% cited limited access to MH-421 seeds, 38% noted high input costs (*e.g.* biofertilizers at Rs. 300-400/ha) and 25% flagged market price volatility as risks. Focus groups emphasized the value of field days, with non-participants (neighbors) showing 60% adoption interest, suggesting a spillover effect (Sharma *et al.,* 2016). These insights align with studies on technology diffusion, where visible success and peer influence accelerate uptake (Dhaka *et al.,* 2016; Meena *et al.,* 2021).

To maximize and scale these benefits, we propose

- **National expansion:** Extend CFLDs to all pulse-growing regions, targeting 5 million hectares by 2030, with funding from national schemes like the NFSM.

Table 1: Yield comparison between demonstration and farmers' practice plots (2017-2022).

Year	Farmers' practice (q/ha)	Demonstration (q/ha)	Extension gap (q/ha)	% Increase	Technology gap (q/ha)	Technology index (%)
2017-18	5.90	7.80	1.90	32.20	2.20	22.0
2018-19	4.85	6.45	1.60	32.99	3.55	35.5
2019-20	5.80	6.70	0.90	15.52	3.30	33.0
2020-21	6.10	7.80	1.70	27.87	2.20	22.0
2021-22	6.20	7.92	1.72	27.74	2.08	20.8
Average	5.77	7.33	1.56	27.26	2.67	26.7

Table 2: Economic analysis of demonstration and farmers' practice plots (2017-2022).

Year	Cost of cultivation (Rs./ha)		Gross returns (Rs./ha)		Net returns (Rs./ha)		B:C ratio	
	FP	D	FP	D	FP	D	FP	D
2017-18	15,026	16,190	21,450	26,567	6,424	10,377	1.43	1.64
2018-19	14,850	17,500	26,675	33,275	11,825	15,775	1.80	1.90
2019-20	14,270	16,190	22,450	26,567	8,180	10,377	1.57	1.64
2020-21	15,780	16,982	32,940	42,120	17,160	25,138	2.09	2.48

Note: FP- Farmers' practice, D- Demonstration.

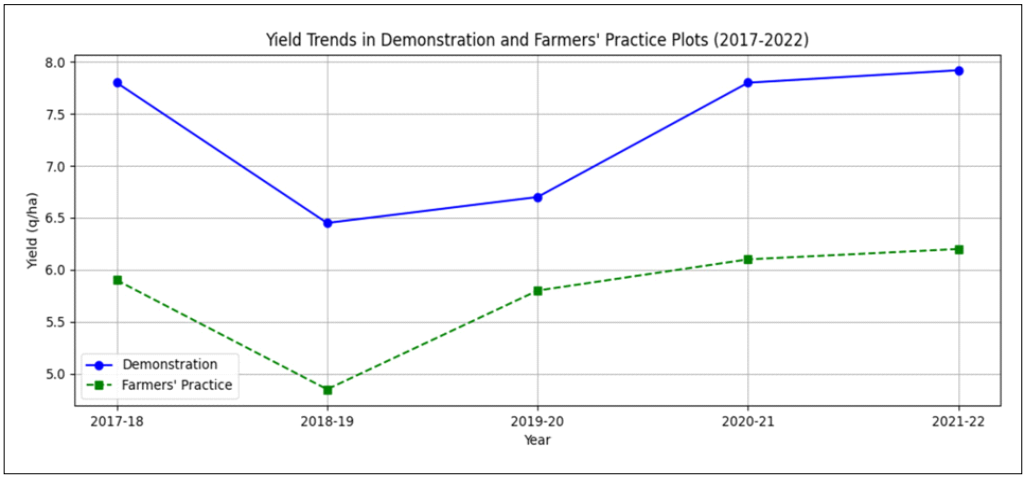


Fig 1: Yield trends in demonstration and farmers' practice plots (2017-2022).

- **Seed infrastructure:** Establish seed hubs to ensure year-round availability of varieties like MH-421, aiming for 50% coverage of summer moong acreage within five years.
- **Farmer training:** Institutionalize annual workshops and digital extension (*e.g.*, mobile apps) to reach 80% of farmers, focusing on integrated nutrient and pest management.
- **Economic incentives:** Subsidize inputs by 30-50% and guarantee a minimum support price (MSP) of Rs. 7,000/q to mitigate market risks.
- **Research agenda:** Fund longitudinal studies on soil health, water efficiency and climate resilience under CFLD systems to quantify environmental benefits.

CFLDs represent a replicable blueprint for modernizing agriculture, empowering farmers and advancing India's pulse self-sufficiency goals. By aligning research, policy and practice, this model can transform rural economies and ensure sustainable food systems for future generations.

CONCLUSION

This study confirms the profound impact of CFLDs on summer moong production in Sonipat, Haryana. The 27.26% yield increase and 43.4% rise in net returns demonstrate that improved technologies can bridge productivity gaps, boost profitability and enhance livelihood security for smallholders. The superior B: C ratio (2.14 vs. 1.83) and lower yield variability (8.5% vs. 10.2%) further highlight the interventions' economic and agronomic viability. These results resonate with broader evidence on CFLDs as an effective extension tool for pulses across India. Additionally, integrating policy-level insights drawn from this study-such as the role of CFLDs in shaping extension strategies and public investment priorities-would provide a valuable dimension. Comparisons with similar CFLD programs in other Indian regions could further contextualize the success achieved in Sonipat and highlight its replicability.

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Conflict of interest

All authors declared that there is no conflict of interest.

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