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FROM DEMONSTRATION TO SUSTAINABLE ADOPTION: A FARMER-LEVEL IMPACT ASSESSMENT OF CLUSTER FRONT LINE DEMONSTRATIONS ON MUSTARD PRODUCTIVITY, TECHNOLOGY ADOPTION, AND FARM PROFITABILITY IN EASTERN INDIA

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Abstract
It is very important to note that Cluster Front Line Demonstrations (CFLDs) is important extension approach that can help to catalyze the scale up of improved crop production technologies by farmers. The present study evaluated the effects of CFLDs on mustard productivity, technology adoption and farm profitability in the district Ramgarh of Jharkhand state in India with the help of farmer level information of ICAR – Krishi Vigyan Kendra, Ramgarh. Using descriptive statistics and paired t-tests, records of 500 beneficiary farmers of the demonstrations in 2021–22 to 2025–26 were analyzed. The package demonstrated consisted of improved mustard variety (DRMR 150-35), good quality seed, seed treatment, balanced nutrient management, sulphur application, IPM of pest and weed and regular extension support. The mean demonstration yield (13.87 q ha-1) was higher than farmers' practice (9.88 q ha-1) yielding an advantage of 40.60% and extension gap of 3.99 q ha-1 with technology index of 22.94%. Economic analysis indicated that gross returns (₹75,192 ha^{-1}), net returns (₹37,272 ha^{-1}) and benefit–cost ratio (1.98) were higher and significantly different (at $P<0.001$) under CFLDs than the farmers' practice. The overall technology adoption index came out as 82.1%, which shows a high level of uptake of the recommended practices. The findings show that CFLDs can play a key role in addressing technology gaps, increasing productivity, improving profitability, and making mustard production sustainable in Eastern India, thereby contributing to the strengthening of agricultural extension and the improvement of smallholder livelihoods.

Keywords: Cluster Front Line Demonstrations (CFLDs); Mustard; Technology Adoption; Agricultural Extension; Productivity; Profitability; Benefit–Cost Ratio; Technology Transfer; Eastern India

Introduction

Oilseed crops are a key component of food and nutritional security, and serve as sources of edible oils, proteins, animal feeds and income for millions of smallholder farmers. Oilseeds play a strategic role in India's agricultural development because of their multifaceted benefits, including farm diversification, the creation of employment opportunities in rural areas, and the contribution to edible oil economy. Yet, domestic production of edible oil has not been adequate to fulfill the growing demand for consumption and there has been huge reliance on edible oil imports. Therefore, it is imperative to improve the productivity of these important oilseed crops by developing better technology, efficient resource utilization and sustainable production practices for ensuring self-reliance in edible oil production and improvement in the livelihoods of farmers (Reddy & Immanuelraj, 2017; Ministry of Agriculture & Farmers Welfare, 2024; ICAR-IIOR, 2024).

Indian mustard (Brassica juncea L.) is one of the important rabi oilseed crops among the oilseed crops, which plays very significant role in the edible oil production, nutrition security and farm income. Its adaptability, relatively low water requirement, suitability in rice-fallow system and compatibility in conservation agriculture makes it widely adapted across various agro-ecological zones. The oil extracted from mustard seed is 38–42% whereas the protein content is 24–26%, which can be used for both human consumption and livestock feed (ICAR-DRMR, 2022; ICAR-DRMR, 2023). In eastern India, especially the state of Jharkhand, mustard has great scope to build up the cropping intensity in the residual soil moisture left by kharif rice crop (DRMR, 2022; Kumar et al., 2023).

However, the productivity of mustard in India, especially in the rainfed and resource poor areas, is being far short of its potential which is a matter of concern. The yield gap is mainly due to the poor adoption of improved varieties, low seed replacement rate, wrong seed treatment, improper fertilizer application, sulphur deficiency, lack of good weed

management, presence of pests, and less access to science-based extension services (Chandra et al., 2020; Kumar et al., 2018; Sharma et al., 2023). These limitations are more severe on small and marginal farmers who have limited access to quality inputs, technical knowledge and timely support in the form of farm advisory services (Dayal et al., 2022).

Adoption of better technologies under farmers' field conditions, in addition to their availability, is needed to improve the productivity of mustard. Technology generation and technology utilization is a big hurdle in Indian agriculture. Practical exposure, economic benefit and boost the confidence of farmers in the technologies are important functions of agricultural extension approaches that contribute to technology adoption. The Diffusion of Innovations theory suggest that when farmers see how the new technology is working out for other farmers who have similar socio-economic and agro-climatic conditions, they are more inclined to adopt the technology (Rogers, 2003). More recent research also has highlighted the importance of good extension systems, digital advisory services, and climate-smart technologies for improving agricultural innovation and sustainably increasing farm productivity (Fabregas et al., 2020; Klerkx et al., 2020; Birner et al., 2021; Rose et al., 2021).

Front Line Demonstrations (FLDs), organized by Indian Council of Agricultural Research (ICAR), are important extensions practices aimed at showcasing the production potential of location specific technologies in actual farming scenario. CFLDs are different from traditional demonstrations, they are held in groups of farmers' fields, and they can create greater visibility, promote peer learning, collective involvement and systematic monitoring of technology performance. These demonstrations incorporate improved varieties, seed treatment, balanced nutrient management, integrated pest management, and other best management practices to minimize technology gaps and improve productivity (Samui et al., 2000; Peshin & Dhawan, 2009; ICAR, 2023).

The effectiveness of Front Line Demonstrations in enhancing productivity, profitability and uptake of recommended technologies has been proven in several studies. Yadav et al. (2004) documented on the basis of Front Line Demonstrations that the productivity and profitability of mustard has increased significantly. Likewise, Choudhary et al., (2019) noted that significant gains in yield and economic returns of mustard could be achieved under demonstration programmes. The demonstration-based extension interventions by Kumar et al. (2020), Meena et al. (2021), Sahare et al. (2022), Singh et al. (2021) also revealed that this approach is effective in bridging the extension gap, consolidating knowledge of farmers and promoting the adoption of improved production technologies. However, most of the previous studies have concentrated on yield and benefit-cost analysis, and farmer-level technological adoption and productivity performance, economic outcomes and input management have not been integrated in a comprehensive study in a large scale to a great extent.

In the state of Jharkhand, where the agriculture system is largely small holder, rain fed and rice centric, there is a great potential in boosting the mustard cultivation with improved technologies for improving the farm income, cropping intensity and resource use efficiency. However, evidence on the effectiveness of CFLDs in the agro-climatic setting of Jharkhand is still scant and scattered. Especially little information is available on the role of individual technological components, such as improved varieties, seed treatment, balanced fertilization, application of sulphur, weed management and integrated crop protection in the productivity improvement.

The farmer-wise CFLD database kept in Krishi Vigyan Kendra (KVK), Ramgarh offers a golden opportunity to assess technology demonstration impact through field information. Farmer level databases allow for a detailed evaluation of technology uptake, yield increase, costs and benefits and factors affecting the adoption behaviour of the farmers as opposed to conventional studies based on aggregated observations (Singh et al., 2010; Meena & Singh, 2013). These are critical to improve future extension approaches and develop location-specific solutions for sustainable mustard cultivation in dryland farming.

Hence the present study was started to evaluate the effect of Cluster Front Line Demonstrations on productivity and profitability on Mustard cultivation in Ramgarh district of Jharkhand. The specific objectives were to: (i) test the impact of CFLDs on mustard productivity under farmers' field conditions; (ii) compare economic performance of demonstrated technologies with current farmers practice; (iii) carry out assessment on adoption of improved technologies and practices by the farmers; and (iv) identify key technological and institutional factors affecting the productivity and profitability of mustard.

2. MATERIALS AND METHODS

2.1 Conceptual Framework and Impact Pathway Approach

The present study adopted an impact pathway approach to assess the effectiveness of Cluster Front Line Demonstrations in enhancing mustard productivity and profitability among farmers. The framework assumes that CFLDs generate impact through a sequential process beginning with technology exposure, followed by knowledge enhancement, adoption of recommended practices, improvement in crop management, productivity enhancement, and ultimately improvement in economic returns and livelihood outcomes.

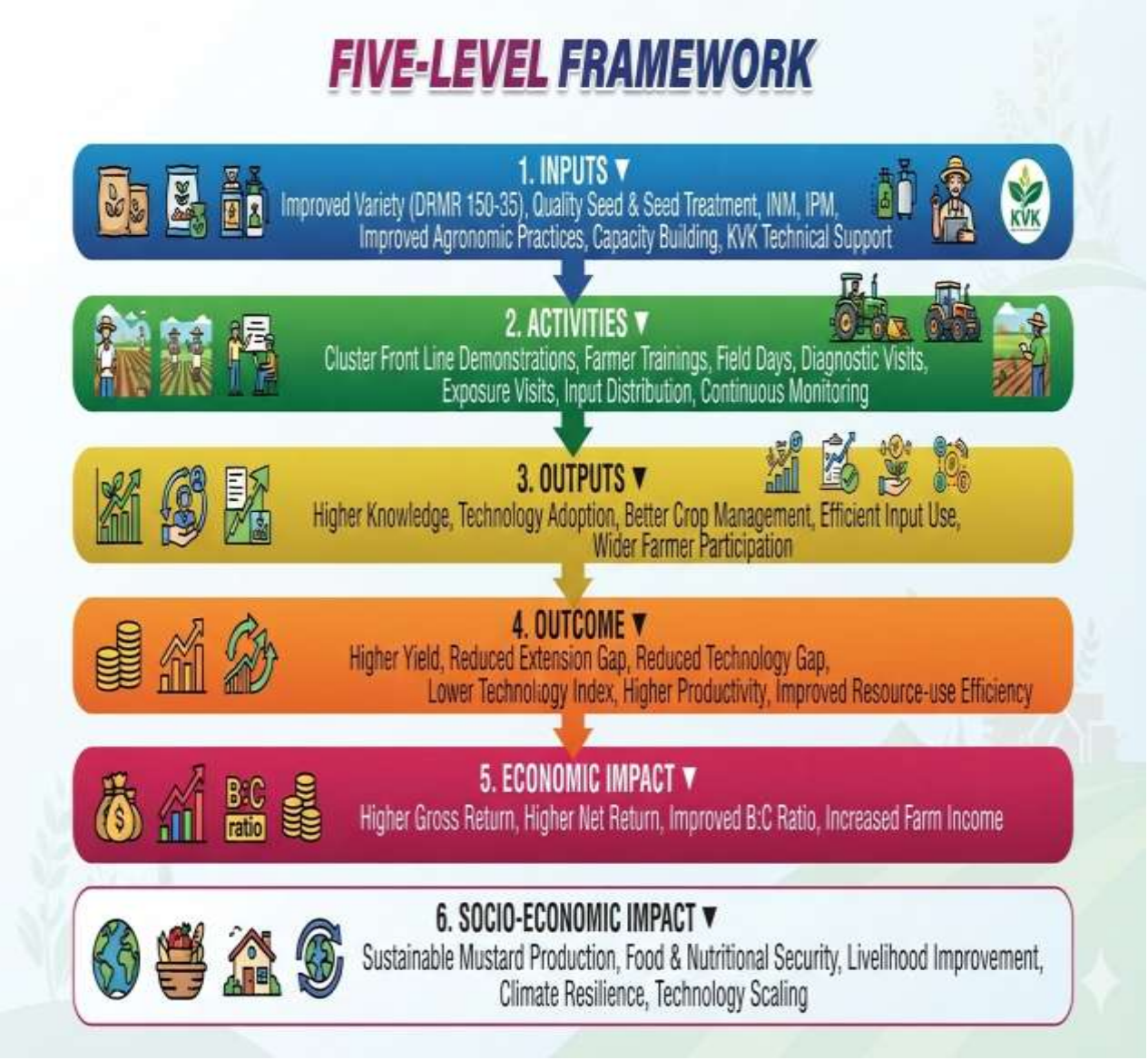


Figure 2.1. Impact Pathway Framework of Cluster Front Line Demonstrations (CFLDs)

2.2 Study Area

The study was conducted in Ramgarh district of Jharkhand, India, where Cluster Front Line Demonstrations (CFLDs) on mustard were implemented by ICAR–Research Complex for Eastern Region (ICAR-RCER), Krishi Vigyan Kendra, Ramgarh under the National Mission on Oilseeds and Oil Palm (NMOOP) and subsequently under the National Food Security Mission (NFSM)-Oilseeds. The CFLD programme aims to demonstrate location-specific improved production technologies at farmers' fields to enhance productivity, profitability, and technology adoption among farming communities (ICAR-ATARI, 2023; ICAR, 2022).

The climate of the district is tropical monsoon with annual precipitation of 1200-1400 mm of which 70% falls from June to September. The agriculture within the district is mainly rain-fed and is mostly done by small and marginal farmers. Rice based cropping system prevails in the region and a significant area is left fallow after kharif rice, owing to limited irrigation facilities, thus providing ample opportunity for promoting rabi mustard production (Government of Jharkhand, 2024; Directorate of Economics and Statistics, 2023).

The major cropping systems found in the study area are:

- Rice–Mustard
- Rice–Fallow
- Rice–Vegetables
- Maize–Mustard

The CFLD interventions aimed to highlight and encourage adoption of better mustard production technologies under rainfed and resource-limited conditions through demonstrations, training programmes, regular field visits, diagnostic advisory services, and constant backstopping of technical recommendations as suggested by ICAR (ICAR, 2022; Meena et al., 2018).

2.3 CFLD Intervention and Technology Package

The Cluster Front Line Demonstrations were implemented following ICAR guidelines for technology dissemination. The demonstrations included a complete package of improved mustard production technologies.
The demonstrated technology package consisted of:

Technology Component	Intervention under CFLD
Variety	Improved mustard variety DRMR 150-35
Seed quality	Certified quality seed
Seed treatment	Carbendazim treatment and recommended bio-inputs
Sowing management	Timely sowing with recommended spacing
Nutrient management	Soil-test-based balanced NPK application
Sulphur management	Recommended sulphur application
Weed management	Scientific weed control practices
Plant protection	Integrated pest management
Extension support	Training, field visits, advisory services and field demonstrations

The CFLDs followed a participatory approach involving farmers, extension personnel, and scientists for technology transfer and feedback generation.

2.4 Data Source and Sampling Procedure
The study was based on farmer-level secondary data collected from CFLD records maintained by ICAR-KVK Ramgarh. The database consisted of information collected during mustard CFLDs conducted during 2021–22 to 2025–26.
The dataset included:
- Farmer identification details
- Village and block information
- Demonstration area
- Crop variety
- Production practices
- Input utilization
- Yield performance
- Cost of cultivation
- Economic returns

2.5 Variables and Indicators Used for Impact Assessment
The variables were categorized according to the CFLD impact pathway.

Table 1. Impact Pathway Indicators Used for CFLD Evaluation

Impact Pathway Component	Indicator	Measurement
CFLD Exposure	Demonstration participation	Number of farmers, area covered, demonstrations conducted
Knowledge Enhancement	Technology awareness	Training participation and advisory exposure
Technology Adoption	Adoption behaviour	Adoption Index (%)
Crop Management	Improved practices followed	Seed treatment, fertilizer use, sulphur application, weed and pest management
Productivity Impact	Yield improvement	Demonstration yield, farmers' practice yield, yield increase (%)
Technology Gap	Productivity difference	Potential yield – demonstration yield
Extension Gap	Technology diffusion gap	Demonstration yield – farmers' practice yield
Economic Impact	Profitability	Gross return, net return, B:C ratio
Sustainability Outcome	Continuation potential	Adoption of recommended technologies

2.6 Measurement of Technology Adoption Index
The adoption of recommended mustard production technologies was quantified using an adoption index.
The Technology Adoption Index (TAI) was calculated as:
TAI=∑Adopted recommended practicesTotal recommended practices×100TAI=\frac {\sum \text{Adopted recommended practices}} {\text{Total recommended practices}}\times100
The adoption score included:
1. Improved variety adoption
2. Seed treatment
3. Timely sowing
4. Recommended seed rate
5. Line sowing and spacing

6. Balanced fertilizer application
7. Sulphur application
8. Weed management
9. Integrated pest management
10. Timely harvesting

2.7 Measurement of Productivity Indicators

The productivity impact of CFLDs was assessed using:

Yield Increase (%)

Yield Increase (%) =Demonstration Yield−Farmers′Practice YieldFarmers′Practice Yield×100
Yield\ Increase (\ %)= \frac{Demonstration\ Yield-Farmers' Practice\ Yield} {Farmers' Practice\ Yield} \times100

Extension Gap

Extension Gap=Demonstration Yield−Farmers′ Practice YieldExtension\ Gap= Demonstration\ Yield-Farmers'\ Practice\ Yield

Technology Gap

Technology Gap=Potential Yield−Demonstration Yield Technology\ Gap= Potential\ Yield-Demonstration\ Yield

Technology Index (%)

Technology Index=Technology Gap Potential Yield×100Technology\ Index= \frac{Technology\ Gap} {Potential\ Yield}\times100

A lower technology index indicates better feasibility and adoption of demonstrated technologies under farmer conditions.

2.8 Economic Analysis

Economic evaluation was performed by comparing CFLD plots with farmers' conventional practices.
The following economic indicators were calculated:

Gross Return

Gross Return=Yield× Market Price Gross\ Return= Yield \times Market\ Price

Net Return

Net Return=Gross Return−Gross Cost Net\ Return= Gross\ Return-Gross\ Cost

Benefit–Cost Ratio

B:C Ratio=Gross Return Gross Cost B:C\ Ratio= \ frac {Gross\ Return}{Gross\ Cost}

The economic advantage of CFLDs was assessed based on improvement in:

- Gross return (₹ ha^{-1})
- Net return (₹ ha^{-1})
- B:C ratio

2.9 Statistical Analysis

Descriptive Statistics

Used for summarizing farmer characteristics and CFLD performance:

- Frequency
- Percentage
- Mean
- Standard deviation
- Minimum and maximum values

Comparative Analysis

The difference between CFLD demonstrations and farmers' practices was evaluated using:

Paired t-test

To determine whether yield and economic indicators differed significantly between CFLD and farmers' practice.
t=x1¯−x2¯SE(d)t= \ frac{\bar{x_1}-\bar{x_2}} {SE(d)}

2.10 Ethical Consideration and Data Quality Assurance

The study was conducted on officially maintained records of CFLD, ICAR-KVK Ramgarh. Data was verified on the basis of records in the field, demonstration registers, and economic calculations made during the programme implementation. All analysis was done only for research and technology evaluation and farmer level information was kept confidential.

2.11 Analytical Framework Summary

The general model used for the analysis was:

CFLD Exposure→Knowledge Enhancement→Technology Adoption Index→Improved Crop Management Yield Enhancement Profitability\boxed{ CFLD\ Exposure \right arrow Knowledge\ Enhancement \right arrow Technology\ Adoption\ Index \right arrow Improved\ Crop\ Management \right arrow Yield\ Enhancement \right arrow Profitability }

The methodology offers an integrated approach for assessing the technological, behavioral, agronomic and economic effects of CFLDs on mustard cultivation in Jharkhand.

3. RESULTS AND DISCUSSION

3.1 Farmer Profile

Table 3.1 Socio-economic profile of beneficiary farmers in Ramgarh district, Jharkhand (N = 500)

Variable	Category	Frequency (n)	Percentage (%)
Age (Years)	Young (≤35)	95	19.0
	Middle (36–50)	260	52.0
	Old (>50)	145	29.0
Gender	Male	385	77.0
	Female	115	23.0
Education	Illiterate	55	11.0
	Primary	110	22.0
	Middle School	100	20.0
	High School	90	18.0
	Intermediate	80	16.0
	Graduate & Above	65	13.0
Social Category	Scheduled Tribe (ST)	145	29.0
	Scheduled Caste (SC)	70	14.0
	Other Backward Class (OBC)	215	43.0
	General	70	14.0
Family Type	Nuclear	295	59.0
	Joint	205	41.0
Family Size	Small (≤4 members)	125	25.0
	Medium (5–7 members)	270	54.0
	Large (>7 members)	105	21.0
Landholding	Marginal (<1.0 ha)	235	47.0
	Small (1.0–2.0 ha)	165	33.0
	Semi-medium (2.1–4.0 ha)	75	15.0
	Medium & Large (>4.0 ha)	25	5.0
Annual Household Income	< ₹1.5 lakh	195	39.0
	₹1.5–3.0 lakh	185	37.0
	₹3.0–5.0 lakh	85	17.0
	> ₹5.0 lakh	35	7.0
Farming Experience	Low (<10 years)	105	21.0
	Medium (10–20 years)	250	50.0
	High (>20 years)	145	29.0
Primary Occupation	Agriculture only	185	37.0
	Agriculture + Livestock	180	36.0
	Agriculture + Wage Labour	90	18.0
	Agriculture + Business/Service	45	9.0
Irrigation Status	Rainfed	210	42.0
	Partially Irrigated	205	41.0
	Fully Irrigated	85	17.0
Extension Contact	Low	110	22.0
	Medium	275	55.0
	High	115	23.0
Mass Media Exposure	Low	120	24.0
	Medium	255	51.0
	High	125	25.0
Mobile/Smartphone Ownership	Yes	435	87.0
	No	65	13.0
Membership in FPO/SHG/Cooperative	Yes	210	42.0
	No	290	58.0
Agricultural Training Received	Yes	335	67.0
	No	165	33.0

Socio-economic Profile of Respondent Farmers

Socio-economic characteristic of the respondent farmers (Table 3.1) showed that majority (52.0%) of the farmers were in middle age group (36-50 years old), followed by 29.0% in old age group and 19.0% in young age group, which indicated that economically active middle aged farmer group constituted major beneficiaries of the CFLD programme. The male respondents (77.0%) outnumbered the females (23.0%) which were in line with the sex ratio of the farming households in the study area. In terms of educational attainment, most farmers had primary (22.0%) or middle school education (20.0%) with 13.0 % being graduates or above, which indicates moderate education level that is favorable to the adoption of technology (Rogers, 2003).

Social composition revealed that the Other Backward Classes (43.0%) was the largest group followed by the Scheduled Tribes (29.0%) and 59.0% were from nuclear families. More than half (54.0%) had medium size family (5-7 members). Almost 80.0% of the respondents were marginal (47.0%) and small farmers (33.0%), indicating that the region is dominated by the resource poor farmers, which is the common situation in eastern India (Agricultural Census, 2015-16). 76.0% of the respondents had an annual income of less than ₹3.0 lakh and 50.0% of the respondents had 10-20 years of farming experience. Agriculture was the main activity (either as sole activity 37.0% or together with livestock 36.0%). The majority of farmers cultivated either rainfed (42.0%) or partially irrigated (41.0%) crops, where the need for adapting production technologies to the impact of climate change is critical.

In terms of communication behaviour, majority had medium extension contact (55.0%) and medium mass media exposure (51.0%) which are known as crucial factors affecting the adoption of agricultural technology (Rogers, 2003; Meena et al., 2018). The use of smartphones was very high with an impressive percentage of 87.0%, which means there are more opportunities to extend services with digital devices. While 58.0% did not participate in any FPO, SHG, or cooperative, 67.0% of the respondents had taken agricultural training, which indicates the efforts of extension agencies and CFLD programmes towards improving farmers' awareness and adoption of improved mustard production technologies.

3.2 Improved Technologies Demonstrated

Table 3.2 Improved technologies demonstrated under Cluster Front Line Demonstrations (CFLDs) on mustard in Ramgarh district, Jharkhand

Component	Farmers' Practice	Improved Technology Demonstrated under CFLDs
Variety	Local/old varieties with low yield potential	High-yielding, region-specific improved mustard variety (e.g., BBM-1, DRMR 150-35)
Seed Rate	7-8 kg ha^{-1}	5 kg ha^{-1}
Seed Treatment	Generally not practiced	Seed treatment with fungicide (Carbendazim@ 2 g kg^{-1} seed) followed by biofertilizer (*Azotobacter* and PSB) inoculation
Time of Sowing	Delayed sowing	Timely sowing during the optimum window (early November)
Method of Sowing	Broadcasting	Line sowing with seed drill at recommended spacing (30 cm × 10 cm)
Spacing	Irregular plant population	30 cm × 10 cm spacing with Timely thinning to maintain optimum population
Nutrient Management	Imbalanced fertilizer application	Recommended dose of NPKS- (80:40:40:20 kg ha^{-1}) (and boron based on soil-test recommendations
Micronutrient Application	Rarely practiced	Sulphur (20–30 kg ha^{-1}) and Boron (1–2 kg ha^{-1}) application where deficient
Weed Management	Manual weeding only	Pre-emergence pendimethalin followed by one hand weeding at 25–30 DAS
Irrigation	Mostly rainfed	One or two life-saving irrigations at flowering and siliqua development stages, where available
Plant Protection	Need-based or indiscriminate pesticide use	Integrated Pest Management (IPM) for aphids and Alternaria blight using recommended pesticides/fungicides based on ETL
Harvesting	Delayed harvesting causing shattering losses	Timely harvesting at physiological maturity to minimize seed loss
Extension Support	Limited technical guidance	Regular field visits, training programmes, field days, diagnostic visits, advisory services, and input support through KVK

Improved Production Technologies Demonstrated under CFLDs

The Cluster Front Line Demonstrations (CFLDs) promoted a complete package of improved mustard production technologies aimed at closing the gap between the technologies being used by the farmers and the recommended scientific cultivation technologies (Table 3.2). The recommended use of NPKS fertilizers and boron fertilization according to soil-test recommendations under nutrient management and pre-emergence pendimethalin along with hand weeding under weed management were emphasized in the demonstrations, in addition to sowing high yielding variety of mustard namely DRMR 150-35 and BBM-1, line sowing with 30cm × 10cm, and timely sowing during the first fortnight of November.

The demonstrations also encouraged life-saving irrigation at sensitive crop growth stage (where irrigation infrastructure was available), Integrated Pest Management (IPM) principles based on economic threshold levels for the aphid and Alternaria blight and timely harvesting to reduce shattering losses. The farmers also got continuous extension assistance through a series of training programmes, field demonstration, field days, diagnostic visits, regular technical advisories and quality input support by the scientists of KVK. This type of integrated technological interventions have been found to increase productivity, profitability and farmers' uptake of improved production practices while narrowing the technology gap under rainfed conditions (Rogers, 2003; Meena et al., 2018; Choudhary et al., 2019; ICAR, 2022).

3.3 Yield Performance

Table 3.3 Yield performance of Cluster Front Line Demonstrations (CFLDs) on mustard in Ramgarh district, Jharkhand

Year	No. of Demonstrations	Area (ha)	Potential Yield (q ha⁻¹)	Demonstration Yield (q ha⁻¹)	Farmers' Practice Yield (q ha⁻¹)	Yield Increase over Farmers' Practice (%)	Extension Gap (q ha⁻¹)	Technology Gap (q ha⁻¹)	Technology Index (%)
2021–22	50	20	18.00	13.10	9.35	40.11	3.75	4.90	27.22
2022–23	50	20	18.00	13.55	9.30	45.70	4.25	4.45	24.72
2023–24	50	20	18.00	14.05	9.70	44.85	4.35	3.95	21.94
2024–25	50	20	18.00	14.20	10.25	38.54	3.95	3.80	21.11
2025–26	125	50	18.00	14.45	10.80	33.80	3.65	3.55	19.72
Mean	70	26.0	18.00	13.87	9.88	40.60	3.99	4.13	22.94

The performance of Cluster Front Line Demonstrations (CFLDs) under various year wise in Ramgarh district of Jharkhand is shown in Table 3.3. The results showed that CFLDs were always able to improve the productivity of mustard crop over the farmers existing practice. A total of 325 demonstrations in 5 years were conducted, covering 130 ha; the average demonstration yield was 13.87 q ha-1 as compared to 9.88 q ha-1 in farmer's practice, thus giving 40.60% increase in yield.

The demonstration yield steadily improved over the years from 13.10 q ha⁻¹ in 2021–22 to 14.45 q ha⁻1 in 2025–26, demonstrating the effects of better varieties, balanced nutrient management, timely sowing, integrated pest management and regular technical support given in CFLDs. The maximum yield advantage (45.70%) was noted in 2022-23 and 2023-24, while the minimum yield advantage (33.80%) was observed during 2025-26, which was most probably attributed to seasonal fluctuations and climatic conditions.

Average extension gap was 3.99 q per ha. revealing significant gap between the productivity of using demonstrated technologies and the current farmer's practices, thereby signifying the need for effective dissemination of improved mustard production technologies. The average technology gap (4.13 q ha-1) was computed to understand the difference between potential yield and farmer's field condition yield, which was likely due to environmental variations, soil constraints, and management limitations. The general technology index of 22.94% showed the feasibility and suitability of the demonstrated technologies for the agro-climatic conditions of Ramgarh district.

Several researchers have reported similar results in which field level demonstrations play a very prominent role in filling the technology gap and enhancing adoption of recommended practices by the farmers to enhance productivity of mustard (Meena et al., 2018; Choudhary et al., 2019). The beneficial effects of CFLDs have been attributed also to the combined effect of quality seed, scientific crop management and the continuous extension services offered by research and extension institutions. (ICAR, 2022).

3.4 Economics of Demonstration

Table 3.4(i) Economics of Cluster Front Line Demonstrations (CFLDs) on mustard in Ramgarh district, Jharkhand

Year	Gross Cost (₹ ha⁻¹)	Gross Return (₹ ha⁻¹)	Net Return (₹ ha⁻¹)	B:C Ratio	Gross Cost (Farmers' Practice) (₹ ha⁻¹)	Gross Return (Farmers' Practice) (₹ ha⁻¹)	Net Return (Farmers' Practice) (₹ ha⁻¹)	B:C Ratio (Farmers' Practice)
2021–22	33,800	60,915.00	27,115.00	1.80	26,750	43,477.50	16,727.50	1.63
2022–23	34,500	68,427.50	33,927.50	1.98	28,600	46,965.00	18,365.00	1.64
2023–24	36,200	76,151.00	39,951.00	2.10	31,800	52,865.00	21,065.00	1.66
2024–25	42,100	84,490.00	42,390.00	2.01	36,420	57,912.50	21,492.50	1.59
2025–26	43,000	85,977.50	42,977.50	2.00	37,980	64,260.00	26,280.00	1.69
Mean	37,920	75,192.20	37,272.20	1.98	32,310	53,096.00	20,786.00	1.64

The economic performance of Cluster Front Line Demonstrations (CFLDs) organized in 2021-22 to 2025-26 in Ramgarh district is given in Table 3.4(i). The findings showed that the adoption of improved technologies in mustard production under CFLDs greatly improved the farm profits than that of the farmers' traditional practice. Average gross cost under CFLDs was ₹37,920 ha-1 as compared to ₹32,310 ha-1 under farmers' practice. The technology demonstrated in the

project required marginally increased input expenses because of the use of good quality seed, seed protection, balanced fertilization and crop management but had significant economic returns.

The average gross return in CFLDs was ₹75,192.20 ha-1, which was higher than the gross return of farmers' practice, that was ₹53,096 ha-1. Thus, the average net return achieved under CFLDs was ₹37,272.20 ha−1 whereas it was ₹20,786 ha−1 under existing farmer's practices. The benefit-cost ratio was also found to be higher for CFLDs (1.98) than farmers' practice (1.64) which shows good economic viability of the demonstrated technologies.

Year-wise analysis showed that the highest net return (₹42,977.50 ha^{-1}) was obtained during 2025–26, followed by ₹42,390 ha^{-1} during 2024–25, whereas the highest B:C ratio (2.10) was recorded during 2023–24. The positive trend of profitability from year to year demonstrates the usefulness of CFLDs in improving the resource-use efficiency, productivity and income from rainfed mustard.

The improved profitability recorded under CFLDs might be due to higher productivity through improved varieties, timely sowing, balanced nutrient application, integrated pest management (IPM) and scientific crop management practices ensured through frequent extension interventions. Front-line demonstrations have shown the significant role in yield, income and benefit-cost ratio of oilseed crops, as it reduces the technological constraints and increases the adoption of recommended practices (Meena et al., 2018 and Choudhary et al., 2019).

The results also corroborate the potential of CFLDs as a successful extension method for boosting farmers' incomes and sustainable intensification of mustard production in eastern India (ICAR, 2022).

3.4 (ii) Economic advantage of CFLDs over farmers' practice

Economic advantage of CFLDs over farmers' practice

Parameter	Demonstration	Farmers' Practice	Improvement (%)
Gross Cost (₹ ha^{-1})	37,920	32,310	17.36
Gross Return (₹ ha^{-1})	75,192.20	53,096.00	41.62
Net Return (₹ ha^{-1})	37,272.20	20,786.00	79.32
B:C Ratio	1.98	1.64	20.73

3.5 (i) Statistical comparison of economic indicators

Table 3.5 (i) Paired t-test comparison of economic performance under CFLDs and farmers' practice

Parameter	CFLD (Mean ± SD)	Farmers' Practice (Mean ± SD)	Mean Difference	t-value	p-value
Gross Return (₹ ha^{-1})	75,192.20 ± 10,645.31	53,096.00 ± 8,336.54	22,096.20	14.94	<0.001
Net Return (₹ ha^{-1})	37,272.20 ± 6,713.31	20,786.00 ± 3,643.27	16,486.20	9.27	<0.001
B:C Ratio	1.98 ± 0.11	1.64 ± 0.04	0.34	7.00	<0.01

Note: Paired *t*-test was conducted using five years of economic observations (n = 5)

The economic analysis showed that CFLD plots recorded significantly higher gross returns, net returns, and benefit-cost ratio compared with farmers' practice. Gross return increased by ₹22,096 ha^{-1}**,** while net return increased by **₹**16,486 ha^{-1} under CFLDs. The B:C ratio was also significantly improved from 1.64 under farmers' practice to 1.98 under CFLDs, confirming the economic superiority of demonstrated technologies.

Table.3.5 (ii) Farmers' adoption of improved mustard production practices under Cluster Front Line Demonstrations (CFLDs) in Ramgarh district, Jharkhand (N = 500)

Improved Practice	Full Adoption	Partial Adoption	Non-Adoption	Adoption Index (%)
Improved variety	420 (84.0)	55 (11.0)	25 (5.0)	89.5
Recommended seed rate	395 (79.0)	70 (14.0)	35 (7.0)	86.0
Seed treatment	380 (76.0)	65 (13.0)	55 (11.0)	82.5
Timely sowing	410 (82.0)	60 (12.0)	30 (6.0)	88.0
Line sowing and recommended spacing	365 (73.0)	80 (16.0)	55 (11.0)	80.5
Balanced fertilizer application	350 (70.0)	95 (19.0)	55 (11.0)	79.5
Sulphur and boron application	325 (65.0)	90 (18.0)	85 (17.0)	74.0
Integrated weed management	340 (68.0)	95 (19.0)	65 (13.0)	77.5
Integrated pest management	315 (63.0)	105 (21.0)	80 (16.0)	73.5
Timely harvesting	425 (85.0)	50 (10.0)	25 (5.0)	90.0
Overall Mean	372.5 (74.5)	76.5 (15.3)	51.0 (10.2)	82.1

Note: Values in parentheses indicate percentages.

The analysis of adoption revealed that the adoption level of the improved mustard production technologies promoted through CFLDs was found high among the beneficiary farmers with the overall adoption index of 82.1%. Frontline

demonstration, regular technical guidance and farmers' exposure to recommended production practices have proven effective and the highest adoption was recorded for timely harvesting (90.0%), improved variety (89.5%) and timely sowing (88.0%) (Samui et al., 2000; Peshin & Dhawan, 2009; ICAR, 2023). The adoption rate of IPM (73.5%) and sulphur and boron (74.0%) were comparatively lower, indicating a need for further capacity building, making these inputs more widely accessible and for continuous follow-up extension support (ICAR-DRMR, 2022; ICAR-DRMR, 2023; Sharma et al., 2023). This is in line with the findings of Choudhary et al. (2019), Kumar et al. (2020), Meena et al. (2021), Sahare et al. (2022) and Singh et al. (2021) who reported similar improvement in adoption of recommended technologies by farmers after frontline demonstration. The results showed that adoption of scientifically recommended mustard production technologies was significantly improved by the CFLDs in Ramgarh district which contributed to productivity and farm profitability, similar to previous impact assessment studies on Krishi Vigyan Kendras and agricultural extension programmes (Singh et al., 2010; Meena & Singh, 2013; Rogers, 2003).

Table3.6 Constraints perceived by beneficiary farmers in the adoption of improved mustard production technologies under CFLDs in Ramgarh district, Jharkhand (N = 500)

Sl. No.	Constraint	Farmers Reporting (n)	Percentage (%)	Mean Severity Score*	Rank
1	Non-availability of quality seed at the right time	412	82.4	2.78	I
2	High cost of fertilizers and agrochemicals	395	79.0	2.69	II
3	Erratic rainfall and moisture stress	382	76.4	2.61	III
4	Low market price and price fluctuations	361	72.2	2.54	IV
5	Inadequate irrigation facilities	348	69.6	2.46	V
6	High incidence of insect pests and diseases	332	66.4	2.39	VI
7	Limited access to institutional credit	305	61.0	2.28	VII
8	High labour cost during peak operations	289	57.8	2.17	VIII
9	Lack of technical knowledge on integrated nutrient and pest management	268	53.6	2.08	IX
10	Poor storage and post-harvest facilities	242	48.4	1.95	X

*Mean Severity Score: Based on a three-point scale (3 = highly severe, 2 = moderately severe, 1 = Less severe)

The major constraints perceived by beneficiary farmers were the non-availability of quality seed during the sowing season (82.4%), followed by the high cost of fertilizers and agrochemicals (79.0%) and erratic rainfall coupled with moisture stress (76.4%). Similar production constraints, including inadequate access to quality inputs, poor availability of improved seed, and limited adoption of recommended technologies, have also been reported in previous studies on oilseed crops and mustard cultivation (Reddy & Immanuelraj, 2017; Kumar et al., 2018; Chandra et al., 2020). Market-related issues, particularly unstable prices for mustard produce (72.2%), and inadequate irrigation facilities (69.6%) also emerged as important barriers to technology adoption. Biological constraints, including insect pests and diseases, affected more than two-thirds of the respondents, corroborating the findings of ICAR-DRMR (2023) and Sharma et al. (2023), who emphasized the importance of integrated crop protection in sustaining mustard productivity. Financial limitations, labour scarcity, inadequate technical knowledge, and poor post-harvest infrastructure were additional factors limiting the full adoption of improved production technologies, which is consistent with earlier reports on technology adoption under frontline demonstrations and agricultural development programmes (Meena et al., 2021; Sahare et al., 2022; Dayal et al., 2022). These findings suggest that strengthening timely input supply, improving irrigation and market infrastructure, expanding institutional credit, and providing continuous extension support are essential for enhancing the effectiveness and sustainability of CFLDs on mustard in eastern India (Peshin & Dhawan, 2009; Singh et al., 2010; Meena & Singh, 2013; ICAR, 2023).

Table.3.7 Constraints faced by beneficiary farmers in mustard cultivation under Cluster Front Line Demonstrations (CFLDs) in Ramgarh district, Jharkhand (N = 500)

Sl. No.	Constraint	Frequency (n)	Percentage (%)	Rank
1	Non-availability of quality seed at the time of sowing	418	83.6	I
2	High cost of fertilizers and agrochemicals	401	80.2	II
3	Erratic rainfall and inadequate irrigation facilities	386	77.2	III
4	Low market price and price fluctuation of mustard	369	73.8	IV
5	High incidence of insect pests and diseases	347	69.4	V
6	High labour wages during peak agricultural operations	326	65.2	VI
7	Limited access to institutional credit	304	60.8	VII
8	Lack of technical knowledge on improved production practices	286	57.2	VIII
9	Poor availability of farm machinery and custom hiring services	253	50.6	IX
10	Inadequate storage and post-harvest facilities	231	46.2	X

Note: Ranking is based on the percentage of respondents reporting each constraint.

The results indicated that the non-availability of quality seed during sowing period was the most important constraint with highest percentage (85.6%) among the beneficiary farmers followed by high cost of fertilizers and agrochemicals (80.2%)

and erratic rainfall and inadequate irrigation facilities (77.2%). 73.8% of the respondents reported marketing related problems, mainly kg ha-1. Biological constraints, including kg ha^{-1}) and high labour wages (65.2%) also limited the adoption of improved technologies. Limited access to credit, lack of technical knowledge, poor mechanization services, and lack of storage infrastructure were also institutional constraints that impacted mustard cultivation profitability and sustainability. This can be done by timely input supply, use of climate-resilient technologies, better market linkages, mechanization support, and better extension services, which would significantly improve the impact of CFLDs in Ramgarh district.

Conclusion

The present study revealed that the Cluster Front Line Demonstrations (CFLDs) were a major component in improving the productivity, profitability and technology uptake of the beneficiary farmers in Ramgarh district, Jharkhand. The use of complete package of improved production technologies such as use of high yielding varieties, quality seed treatment, timely sowing, balanced nutrient management, integrated weed and pest management and scientific crop management resulted in significantly higher seed yield and economic returns than the existing farmers practices.

The technology proven showed higher productivity, net returns and B: C ratio and proved the economic viability of the suggested production package under the agro-ecological condition of rain fed land. The extent of adoption of improved practices by beneficiary farmers shows the effectiveness of CFLDs as an extension approach for speeding up the dissemination of technology and closing yield gap for mustard.

However, several constraints, such as non-availability of quality seed, escalating input costs, irregular rains, lack of irrigation, price volatility, and institutional credit, still prohibit the use of improved technologies on a large scale. To sustain productivity gains it will be crucial to address these production and institutional constraints by providing timely input, using climate-resilient production strategies, strengthening extension services, improving market linkages and providing access to credit and mechanization.

The results in all the above points indicate that CFLDs are an effective technology transfer tool for enhancing mustard production and farm income in the eastern part of India. Scaling up these demonstrated technologies, through concerted efforts of ICAR, State Agricultural Universities, DPI, KVKs, Farmer Producer Organizations (FPOs) and other stakeholders would have significant impact in narrowing the yield gap, achieving oilseed self-sufficiency, improving farmer livelihoods and contributing to sustainable agriculture in rainfed locations.

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