



## Evaluation of improved fodder sorghum (*Sorghum bicolor*) varieties through frontline demonstrations

VIVEK PRATAP SINGH<sup>1</sup>, AVANISH KUMAR SINGH<sup>1\*</sup>, RAJENDRA PRATAP SINGH<sup>2</sup> and BHUSHAN KUMAR SINGH<sup>2</sup>

Mahayogi Gorakhnath Krishi Vigyan Kendra, Chaukmafi, Pepeganj, Gorakhpur, Uttar Pradesh 273 165, India

Received: 10 January 2026; Accepted: 20 March 2026

### ABSTRACT

The study implementing the Front Line Demonstrations (FLDs) were conducted during 2019–20 to 2023–24 to assess the effect of improved sorghum [*Sorghum bicolor* (L.) Moench] production technologies on productivity, yield gap, economics, and adoption behaviour of farmers in sorghum production. A total of 150 demonstrations covering 20 ha in 33 villages were implemented using improved varieties CSV 24 MF and UPMC 503 along with recommended agronomic practices. The average fodder yield under FLDs was 707.0 q/ha, registering a yield advantage of 25.14% over farmers' practice. Yield Gap I and Yield Gap II analyses indicated that while extension interventions substantially reduced adoption-related yield losses, a moderate gap between potential and realized yields persisted due to agro-climatic and management constraints. Economic analysis revealed that improved technologies increased net returns by ₹15,202.6/ha with a higher benefit-cost ratio (2.57) compared to farmers' practice (2.09), despite a marginal increase in cost of cultivation. Adoption of recommended practices improved markedly after demonstrations, with an overall adoption impact of 248.41%, particularly for seed treatment, fertilizer application, and use of improved varieties. FLDs also resulted in effective varietal replacement of local sorghum cultivars and substantial horizontal spread of improved varieties, with area expansion of 233.33% for CSV 24 MF and 208.33% for UPMC 503. The study concludes that FLDs are an effective extension tool for enhancing sorghum productivity, profitability, and technology adoption under farmers' field conditions.

**Keywords:** Adoption gap index, Benefit-cost ratio, Effective gain, Varietal replacement, Yield gap

Livestock plays a vital role in the Indian agricultural economy by providing income, employment and nutritional security to rural households. However, the productivity of livestock is largely constrained by the inadequate availability of quality fodder, as the country faces a chronic deficit of green and dry fodder. It is estimated that India experiences a deficit of about 11–12% green fodder and 25–30% dry fodder, which adversely affects milk yield and animal health (IGFRI 2019). Enhancing fodder production through high-yielding crops and improved management practices is therefore essential for sustainable livestock development. Sorghum (*Sorghum bicolor* L. Moench) is an important dual-purpose and fodder crop grown widely during the rainy (*kharif*) season due to its high biomass yield, rapid growth, palatability and tolerance to drought and less fertile soils. Improved fodder sorghum varieties such as CSV-24MF and

UPMC-503 have been developed to offer higher green fodder yield, better regeneration capacity and superior nutritive value. Despite their proven potential, adoption of these varieties and recommended production technologies at the farmers' level remains limited, leading to wide yield gaps between research stations and farmers' fields (Kumar *et al.* 2020). Yield gaps in fodder crops are primarily attributed to the use of local or mixed varieties, non-adoption of seed treatment, improper sowing time and imbalanced fertilizer application. Frontline demonstrations (FLDs), implemented by Krishi Vigyan Kendras (KVKs), serve as an effective extension tool to demonstrate the performance of improved technologies under real farm conditions and to generate feedback for researchers and policymakers (Samui *et al.* 2000). FLDs not only help in narrowing the technology and extension gaps but also facilitate faster adoption, varietal replacement and horizontal spread of proven technologies. Keeping this in view, the present study was undertaken to evaluate the impact of FLDs on improved fodder sorghum varieties with respect to green fodder yield, yield gap analysis, economics, adoption of recommended practices and horizontal spread, with the objective of strengthening fodder security and enhancing farm profitability.

<sup>1</sup>Mahayogi Gorakhnath Krishi Vigyan Kendra, Chaukmafi, Pepeganj, Gorakhpur, Uttar Pradesh; <sup>2</sup>Krishi Vigyan Kendra, Narkatiaganj, West Champaran (Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar), Bihar.  
\*Corresponding author email: [avanishsinghicar@gmail.com](mailto:avanishsinghicar@gmail.com)

## MATERIALS AND METHODS

The study was carried out during the rainy (*kharij*) season from 2019–20 to 2023–24 in Gorakhpur district of Uttar Pradesh, which falls under the North Eastern Plain Zone and is characterized by crop–livestock-based farming systems. In total, 150 Frontline demonstrations (FLDs) were conducted across 33 villages, covering an area of 20 ha. Prior to the initiation of demonstrations, a baseline survey was undertaken to assess existing sorghum cultivation practices, constraints and technological gaps. Based on the survey findings, need-based, willing and progressive farmers were selected through group discussions and village-level meetings. Emphasis was given to site accessibility and farmers' readiness to adopt improved practices. The selected farmers were provided with skill-oriented training on improved sorghum production technologies aimed at enhancing green fodder yield. The demonstrations were laid out on farmers' fields and monitored regularly from sowing to harvesting by scientists. Improved sorghum varieties CSV 24 MF and UPMC 503 were demonstrated along with the recommended package of practices, including proper land preparation, recommended seed rate, timely sowing, suitable sowing method, balanced fertilizer application @80:40:40 kg N:P<sub>2</sub>O<sub>5</sub>: K<sub>2</sub>O/ha, seed treatment with carbendazim @2 g/kg seed, and appropriate irrigation management. Field days and farmers' meetings were organized during the crop season to demonstrate the performance of improved technologies and to promote their dissemination among neighbouring farmers. Data on green fodder yield and economic parameters were recorded separately for demonstration plots and farmers' practice plots. Information on technology adoption and horizontal spread was collected using a structured interview schedule. Cost of cultivation, gross and net returns and benefit-cost ratio was computed using the prevailing market prices of inputs and outputs for the respective years. The adoption gap index which represents the percentage deviation of farmers' practices from the recommended improved practices was calculated using the formula suggested by Dubey *et al.* (1981):

$$\text{Adoption gap index (\%)} = \frac{R-A}{R} \times 100$$

Where, R, Total no. of improved practices; A, No. of improved practices actually adopted by the farmer.

Yield parameters of both demonstrations and check involving farmer's practices were recorded. The technology gap, extension gap and technology index were calculated as suggested by Samui *et al.* (2000) and Dayanand *et al.* (2012).

$$\text{Impact on yield (\%)} = \frac{Dy - Fpy}{Fpy} \times 100$$

Where, Dy, Demonstrated yield; Fpy, Farmer practice yield.

$$\text{Extension gap} = Dy - Fpy$$

Technology gap = Potential yield (Py) - Demonstrated yield (Dy)

$$\text{Technology index (\%)} = Py - Dy \times 100 / Py$$

$$\text{Additional cost in improved technology (\₹/ha)} = Cit - Cfp$$

Where Cit, Cost of improved technology (₹/ha); Cfp, Cost of farmers practice (₹/ha)

$$\text{Additional returns (\₹/ha)} = Nrit - Nrpf$$

Where Nrit, Net returns of improved technology (₹/ha); Nrpf, Net returns of farmers practice (₹/ha)

$$\text{Effective gain (\₹/ha)} = Arit - Acit$$

Where, Arit, Additional returns of improved technology (₹/ha); Acit, Additional cost of improved technology (₹/ha)

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross return (\₹/ha)}}{\text{Gross expenditure (\₹/ha)}}$$

The yield gap was also comprising at least two components i.e. Yield gap I and Yield gap II (Mondal 2011). Yield Gap I refer to the difference between potential yield of the variety taken from the variety release committee of the state and farm yield obtained at demonstration plots, while Yield Gap II, reflecting the effects of biophysical and socio-economic constraints, was the difference between yield obtained at the demonstration plot and actual yield obtained on farmers' fields. The yield gaps were estimated as follows:

$$\text{Yield gap I} = [(Y_p - Y_D)/Y_p] \times 100$$

$$\text{Yield gap II} = [(Y_D - Y_F)/Y_D] \times 100$$

Where, Y<sub>p</sub> is the potential yield; Y<sub>D</sub> is the demonstration plot yield; Y<sub>F</sub> is the existing farmers yield.

However, data about adoption and horizontal spread of technologies were collected from the farmers with the help of interview schedule. Data were subjected to suitable statistical methods. The following formulae were used to assess the impact on different parameters of fodder production.

$$\text{Impact on yield (\% Change)} = \frac{YD_p - YC_p}{YC_p} \times 100$$

Where, YD<sub>p</sub>, Yield of demonstrated plot; YC<sub>p</sub>, Yield of control plot.

$$\text{Impact on Adoption (\% Change)} = \frac{A_{ad} - A_{bd}}{A_{bd}} \times 100$$

Where, A<sub>ad</sub>, No. of adopters after demonstration; A<sub>bd</sub>, No. of adopters before demonstration

$$\text{Impact on Horizontal spread (\% change)} = \frac{A_{iad} - A_{bd}}{A_{bd}} \times 100$$

Where, A<sub>iad</sub>, Area increased (ha) after demonstration; A<sub>bd</sub>, Area (ha) before demonstration

## RESULTS AND DISCUSSION

### *Performance of sorghum under front line demonstration:*

The Front Line Demonstrations (FLDs) conducted on fodder sorghum generated robust field-level evidence on the productivity gains achievable through improved varieties and scientific crop management under farmers' conditions. A total of 150 demonstrations were implemented across 33 villages covering 20 ha, providing adequate spatial

and temporal representation to assess the effectiveness of extension-led interventions. The results clearly showed that demonstrated technologies consistently outperformed prevailing farmers' practices across years and varieties.

The performance of fodder sorghum varieties under FLDs is presented in Table 1 and Fig. 1. During 2019–20 and 2020–21, demonstrations with the variety CSV 24 MF recorded an average green fodder yield of 722.50 q/ha, reflecting a yield advantage of 24.69% over farmers' practice (577.5 q/ha). The yield improvement was mainly attributed to the use of certified seed and seed treatment with carbendazim, which enhanced germination, crop stand, and early vigour. Similar yield advantages due to adoption of improved fodder sorghum varieties under FLDs have been reported earlier, highlighting the importance of quality seed and seed health management (Meena *et al.* 2016, Singh *et al.* 2019).

Despite these gains, as presented in Table 1 and Supplementary Fig. 1, the average technology gap under CSV 24 MF remained 278 q/ha, indicating that the varietal potential (1000 q/ha) could not be fully realized under farmers' field conditions. This gap may be attributed to soil fertility variability, sub-optimal nutrient application, and intermittent moisture stress. The technology index of 27.75% suggested moderate feasibility of the demonstrated technology and reflects the influence of agro-climatic and management factors on fodder crop performance (Kumar *et al.* 2018) (Table 1 and Supplementary Fig. 2).

Demonstrations conducted with the variety UPMC 503 during 2021–22 to 2023–24 further confirmed the positive impact of FLDs. The average demonstration yield was 696.70 q/ha, registering a yield advantage of 25.43% over farmers' practice (555 q/ha). A gradual increase in yield over successive years, with the highest yield recorded during 2023–24 (755 q/ha), indicates improved farmer learning and adoption over time. Such trends support earlier observations that FLDs function as experiential learning platforms that strengthen farmers' skills and confidence (Samui *et al.* 2000, Lal *et al.* 2020).

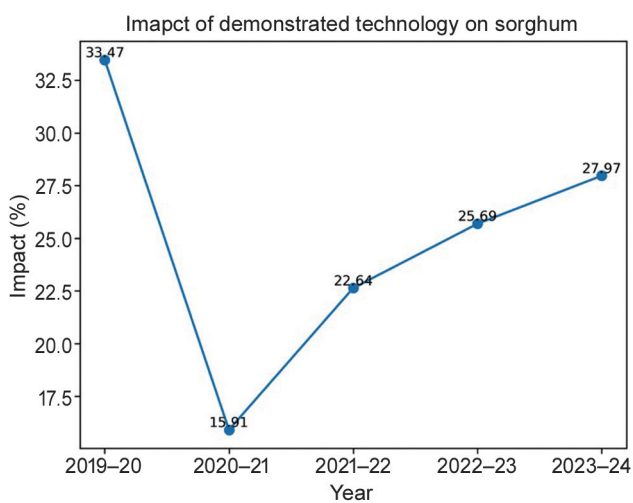


Fig. 1 Effect of demonstrated technology on sorghum.

Table 1 Performance of sorghum under front line demonstration (FLD)

Variety	Year	Technology demonstrated	Potential yield of sorghum variety (CSV 24 MF) (q/ha)	No. of Demo.	Area (ha)	No. of village covered	Average yield (q/ha)		Impact (% change)	TG (q/ha)	EG (q/ha)	TI (%)
							Under FLD programme	*DP				
Sorghum (CSV 24 MF)	2019–20	CSV 24 MF seed + seed treatment with carbendazim @2 g/kg seed	1000	37	4.00	7	807.5 (825–790) *	605	+33.47	193	202.5	19.25
	2020–21	CSV 24 MF seed + seed treatment with carbendazim @2 g/kg seed	1000	23	4.00	6	637.5 (725–550) *	550	+15.91	363	87.5	36.25
Total/Average Sorghum (UPMC 503)	2021–22	UPMC 503 seed + seed treatment with carbendazim @2 g/kg seed	1000	60	8.00	13	722.50 (710–590) *	577.5	+24.69	278	145	27.75
	2022–23	UPMC 503 seed + seed treatment with carbendazim @2 g/kg seed	1000	30	4.00	6	650 (720–650) *	530	+22.64	350	120	35.00
Total/Average	2023–24	UPMC 503 seed + seed treatment with carbendazim @2 g/kg seed	1000	30	4.00	8	755 (780–730) *	545	+25.69	315	140	31.50
	Total/Average			90	12.00	20	696.70	555	+25.43	303.33	141.66	30.33
Overall total/Average				150	20	33	707.00	582.00	+25.14	293.2	143	29.3

\* Figures in parentheses indicate lowest and highest yield of demonstrated farmer. Demo, Demonstration; DP, Demonstrated plot; FP, Farmers' practice; TG, Technology gap; EG, Extension gap; TI, Technology index.

The average technology gap under UPMC 503 (303.33 q/ha) was marginally higher than that of CSV 24 MF, suggesting that varietal potential alone cannot bridge productivity gaps without complementary agronomic management. The extension gap averaged 141.66 q/ha as presented in Table 1 and Supplementary Fig. 3, highlighting the yield losses associated with non-adoption of recommended practices and underscoring the critical role of extension services. Comparable extension gaps in fodder crops under FLDs have been reported by Choudhary *et al.* (2017).

Pooled analysis across all five years revealed an overall average fodder yield of 707.00 q/ha under FLDs, which was 25.14% higher than farmers' practice (582.00 q/ha). The overall extension gap (143 q/ha) and technology index (29.30%) indicated that while the demonstrated technologies are technically sound, their impact could be enhanced through integrated interventions focusing on soil health, timely input supply, and irrigation management. Earlier studies also emphasize that convergence of FLDs with soil testing and advisory services significantly improves adoption and productivity (ICAR 2015, Singh and Chauhan 2021).

From a fodder security and livestock development perspective, the demonstrated yield gains are particularly relevant, as fodder scarcity remains a major constraint to dairy productivity. Improved fodder sorghum varieties offer a viable option for increasing green biomass availability per unit area, thereby supporting enhanced livestock productivity and farm income (Birthal and Jha 2019). Overall, the study reaffirms that FLDs on fodder sorghum are effective extension tools and provide valuable empirical inputs for strengthening fodder development strategies and extension planning.

*Effect of FLDs on yield gap in sorghum varieties:* The data presented in Table 2 clearly illustrate the effect of FLDs on yield gap dynamics in sorghum during 2019–20 to 2023–24. In the variety CSV 24 MF, Yield Gap I showed noticeable variability across years, with values of 19.25% in 2019–20 and 36.25% in 2020–21, resulting in a mean Yield Gap I of 23.17%. This fluctuation indicates year-to-year variation in farmers' management practices and environmental conditions. Yield Gap II for CSV 24 MF ranged from 25.08–13.73%, with a mean of 20.61%, suggesting that FLDs substantially reduced the gap between farmers' practices and recommended technologies, although complete convergence was not achieved.

For the variety UPMC 503, Yield Gap I remained comparatively higher but showed a consistent declining trend from 35.00% in 2021–22 to 24.50% in 2023–24, with an overall mean of 30.33%. This decline reflects gradual improvement in adoption of improved practices and better adaptation of the variety under local conditions. Yield Gap II for UPMC 503 ranged from 18.46–21.85%, with a mean of 20.25%, indicating that while FLDs significantly enhanced yields over farmers' practices, a moderate extension gap persisted. Overall, the results confirm that FLDs are effective in narrowing yield gaps in sorghum, though sustained extension efforts are required to further minimize these gaps.

*Effect of FLDs on economics of sorghum cultivation:* The economic performance of sorghum cultivation under FLDs was evaluated in terms of cost of cultivation, gross monetary returns, net returns (Supplementary Fig. 4), benefit-cost ratio (Supplementary Fig. 5), and effective gain during the period 2019–20 to 2023–24 (Table 3). The analysis revealed that improved technological interventions (IT) consistently outperformed farmers' practices (FP) across all years and varieties, resulting in enhanced profitability with only marginal additional investment.

The cost of cultivation under improved technological interventions was slightly higher than farmers' practice throughout the study period. In the case of sorghum variety CSV 24 MF, the average cost of cultivation under IT was ₹28,618.5/ha compared to ₹27,850/ha under FP, representing an increase of 2.77%. Similarly, for the variety UPMC 503, the average increase in cost of cultivation was 1.87%. The overall additional cost of cultivation across all demonstrations averaged ₹647.4/ha. The marginal increase in cost was mainly attributable to the use of quality seed and seed treatment inputs, which are considered low-cost but yield-enhancing components of the improved package. Comparable findings on modest increases in cultivation cost under FLDs have been reported earlier in fodder and forage crops (Samui *et al.* 2000, Meena *et al.* 2016).

Despite the slight increase in cultivation cost, gross monetary returns (GMR) under FLDs were substantially higher than those obtained under farmers' practice. For CSV 24 MF, the average GMR under improved technology was ₹72,250/ha, which was 24.69% higher than FP (₹57,750/ha). In the case of UPMC 503, the average GMR under IT was ₹82,083.3/ha, reflecting an increase of 25.13% over farmers' practice. The higher GMR recorded under

Table 2 Effect of FLDs on sorghum crops in relation to yield gap during 2019–20 to 2023–24

Variety	Yield gap I (%)			Yield gap II (%)				
	2019–20	2020–21	Mean	2019–20	2020–21	Mean		
Sorghum (CSV 24 MF)	19.25	36.25	23.17	25.08	13.73	20.61		
Variety	Yield gap I (%)				Yield gap II (%)			
	2021–22	2022–23	2023–24	Mean	2021–22	2022–23	2023–24	Mean
Sorghum (UPMC 503)	35.0	31.50	24.50	30.33	18.46	20.44	21.85	20.25

FLDs can be attributed to increased green fodder yield and improved crop performance resulting from adoption of recommended practices. Similar increase in gross returns under FLDs in fodder sorghum and other forage crops have been documented by Kumar *et al.* (2018) and Singh *et al.* (2019).

The improvement in gross returns was reflected in significantly higher net returns under improved technological interventions. For CSV 24 MF, the average net return increased from ₹29,900/ha under FP to ₹43,631.5/ha under IT, resulting in an additional net return of ₹13,731.5/ha. Likewise, for UPMC 503, average net returns increased from ₹34,400/ha to ₹50,583/ha, yielding an additional net income of ₹16,183.3/ha. When data were pooled across all years and varieties, the overall additional net return was ₹15,202.6/ha. These results are in agreement with earlier studies reporting significant enhancement in farm income due to adoption of improved fodder crop technologies under FLDs (Choudhary *et al.* 2017, Lal *et al.* 2020).

The benefit-cost ratio, an important indicator of economic efficiency, was consistently higher under improved technological interventions compared to farmers' practice. For CSV 24 MF, the average BCR increased from 2.08 under FP to 2.53 under IT, while for UPMC 503, it increased from 2.10–2.60. The highest BCR (3.54) was observed for UPMC 503 during 2023–24, indicating efficient utilization of inputs and higher profitability during that season. The overall pooled BCR under improved technology (2.57) was markedly higher than that under farmers' practice (2.09), confirming the economic superiority of demonstrated technologies. Similar improvements in BCR under FLDs have been reported by ICAR (2015) and Singh and Chauhan (2021).

The effective gain, calculated by accounting for additional cost of cultivation over farmers' practice, further substantiated the economic advantage of FLDs. The overall average effective gain was ₹14,555.2/ha, demonstrating that farmers realized substantial monetary benefits even after meeting the additional investment required for improved practices. These findings reaffirm that FLDs are effective in enhancing the economic returns from sorghum cultivation and provide empirical support for the profitability of improved fodder production technologies under farmers' field conditions.

*Effect of FLDs on adoption of sorghum production technologies:* The FLDs significantly improved the adoption of recommended sorghum production technologies among participating farmers (Table 4). Prior to demonstrations, adoption levels of most practices were low, indicating limited awareness and partial use of scientific crop management. Post-demonstration results showed substantial improvement across all technologies, confirming the effectiveness of FLDs as an extension approach.

Adoption of land preparation and FYM application increased from 38.67% before demonstrations to 94.67% after demonstrations, with an impact of 144.83%. The use of recommended sorghum varieties (CSV 24 MF and

Table 3 Effect of FLDs on economics of sorghum cultivation

Crop/Variety	Year	CoC (₹/ha)		CoC increase over FP (%)	GMR (₹/ha)		GMR increase over FP (%)	NR (₹/ha)		NR increases over FP (%)	ACoC in IT (₹/ha)		ANR (₹/ha)	BCR		Effective gain (₹/ha)
		IT	FP		IT	FP		IT	FP		IT	FP		IT	FP	
Sorghum (CSV 24 MF)	2019–20	28,100	27,300	2.93	80,750	60,500	33.47	52,650	33,200	58.58	800	19,450	2.87	2.22	18,650	
	2020–21	29,137	28,400	2.60	63,750	55,000	15.91	34,613	26,600	30.12	737	8,013	2.19	1.94	7,276	
Average		28,618.5	27,850	2.765	72,250	57,750	24.69	43,631.5	29,900	44.35	768.5	13,731.5	2.53	2.08	12,963	
		30,500	29,500	3.39	65,000	53,000	22.64	34,500	23,500	46.81	1000	11,000	2.13	1.80	10,000	
Sorghum (UPMC 503)	2022–23	32,000	31,500	1.59	68,000	54,500	24.77	36,000	23,000	56.52	500	13,000	2.13	1.73	12,500	
	2023–24	32,000	31,800	0.63	11,3250	88,500	27.97	81,250	56,700	43.30	200	24,550	3.54	2.78	24,350	
Average		31,500	30,933.33	1.87	82,083.3	65,333.3	25.12667	50,583	34,400	48.88	566.67	16,183.33	2.60	2.10	15,616.67	
Overall Total/Average		30,347.4	29,700	2.228	78,150	62,300	24.952	47,802.6	32,600	47.066	647.4	15,202.6	2.572	2.094	14,555.2	

CoC, Cost of cultivation; IT, Improved technological interventions; FP, Farmers' practice; GMR, Gross monetary return; ACoC, Additional cost of cultivation; NR, Net returns; ANR, Additional net returns; BCR, Benefit-cost ratio.

Table 4 Effect of FLDs on adoption of sorghum production technology

Technology	No. of adopters (N=150)				Change in No. of Adopter	Impact (% change)
	Before demonstration		After demonstration			
	No of farmers	%	No of farmers	%		
Land preparation and FYM application	58	38.67	142	94.67	+84	144.83
Recommended Varieties (CSV 24 MF and UPMC 503)	38	25.33	138	92.00	+100	263.16
Seed rate (25 kg/ha)	62	41.33	145	96.67	+83	133.87
Seed treatment (carbendazim @2 g/kg seed)	24	16.00	130	86.67	+106	441.67
Time of sowing (May–June)	56	37.33	150	100.00	+94	167.86
Recommended sowing method	80	53.33	150	100.00	+70	87.50
Fertilizer dose (80:40:40 kg N:P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O per ha)	22	14.67	132	88.00	+110	500.00
Overall impact						248.41

UPMC 503) increased markedly from 25.33 – 92.00%, registering an impact of 263.16%, highlighting the strong influence of on-farm varietal demonstrations. Similar trends have been reported earlier in fodder crops, where varietal visibility accelerated adoption (Meena *et al.* 2016, Singh *et al.* 2019).

Adoption of the recommended seed rate (25 kg/ha) increased from 41.33–96.67% (impact: 133.87%), indicating improved understanding of optimum plant population. The most pronounced improvement was observed in seed treatment with carbendazim, where adoption increased from 16.00–86.67%, resulting in a 441.67% impact. This suggests that FLDs effectively addressed knowledge gaps related to seed health management, which is often neglected in farmers' practices (Lal *et al.* 2020).

Complete adoption (100%) was achieved for both recommended time of sowing (May–June) and recommended sowing method, reflecting farmers' confidence in practices that directly influence crop establishment and yield. Adoption of the recommended fertilizer dose (80:40:40 kg N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O per ha) increased from 14.67–88.00%, registering the highest impact (500.00%). This indicates that FLDs were particularly effective in improving nutrient management practices, which typically show low baseline adoption (ICAR 2015).

Overall, FLDs resulted in a cumulative adoption impact of 248.41%, demonstrating their effectiveness in bridging the adoption gap through experiential learning and practical exposure. The results confirm that FLDs play a vital role in enhancing farmers' adoption of improved sorghum production technologies under field conditions.

*Effect of FLDs on varietal replacement and horizontal spread of sorghum:* FLDs significantly influenced varietal replacement and horizontal spread of improved sorghum varieties in the study area (Table 5). Before the intervention, cultivation was largely dominated by old and mixed local varieties, which exhibited low yield potential and unstable performance. The introduction of improved varieties, namely CSV 24 MF and UPMC 503, through FLDs resulted in a clear transition toward scientifically recommended cultivars.

The observed varietal replacement highlights the

effectiveness of FLDs in overcoming farmers' reluctance to adopt new varieties by showcasing their performance under actual field conditions. Improved biomass yield, better crop stand, and uniform growth served as visible and convincing indicators, motivating farmers to replace traditional varieties with improved ones. Similar positive effects of FLDs on varietal replacement in fodder and forage crops have been reported earlier (Samui *et al.* 2000, Meena *et al.* 2016), reinforcing the role of demonstrations in technology diffusion.

The horizontal spread of improved sorghum varieties further confirmed the impact of FLDs. The area under CSV 24 MF increased from 45 ha before demonstrations to 150 ha after demonstrations, reflecting an expansion of 105 ha (233.33%). Likewise, UPMC 503 expanded from 60–185 ha, showing an increase of 125 ha with an impact of 208.33%. This substantial expansion indicates strong farmer acceptance and spontaneous dissemination beyond FLD plots. The relatively greater spread of UPMC 503 may be attributed to its consistent performance and better adaptability to local agro-climatic conditions. Overall, FLDs proved effective in accelerating varietal replacement and scaling up improved sorghum technologies.

In conclusion, FLDs proved effective in enhancing green fodder productivity, profitability and adoption of improved sorghum production technologies under farmers' field conditions. The improved varieties CSV 24 MF and UPMC 503 consistently outperformed farmers' practice, resulting in significant yield enhancement, reduced yield gaps and higher economic returns. The favourable benefit-cost ratio and substantial additional net income highlighted the economic viability of the demonstrated technologies. FLDs also

Table 5 Effect of FLDs on horizontal spread of sorghum variety

Crop	Area (ha)		Change in area (ha)	Impact (%) change)
	Before demonstration	After demonstration		
CSV 24 MF	45	150	+105.00	233.33
UPMC 503	60.00	185	+150.00	208.33

facilitated rapid adoption, varietal replacement and horizontal spread of improved sorghum varieties, indicating strong farmer acceptance. The study underscores the critical role of FLDs as an extension tool for narrowing technology gaps and strengthening fodder availability. Wider dissemination of improved varieties and recommended practices through FLDs can contribute substantially to sustainable livestock production and farm income enhancement in the Gorakhpur district of Uttar Pradesh.

Overall findings of the FLDs played a crucial role in bridging the average technology gap in sorghum production through inclusion of the improved sorghum varieties CSV 24 MF and UPMC 503 in Gorakhpur district of Uttar Pradesh.

#### ACKNOWLEDGMENT

The authors gratefully acknowledge the support, guidance, technical supervision, and financial assistance provided by the ICAR-Agricultural Technology Application Research Institute, Kanpur, Uttar Pradesh for the effective implementation of the Front Line Demonstrations under the FLD programme.

#### REFERENCES

- Birthal P S and Jha A K. 2019. Economic losses due to fodder scarcity in India. *The Indian Journal of Animal Sciences* **89**(1): 1–7.
- Choudhary A K, Yadav D S and Singh A. 2017. Impact of front line demonstrations on productivity of forage crops. *Indian Journal of Extension Education* **53**(3): 45–49.
- Dayanand V R K and Mehta S M. 2012. Boosting mustard production through front line demonstrations. *Indian Research Journal of Extension Education* **12**(3): 121–23.
- Dubey V K, Singh S B, Saini R and Saini S P. 1981. Gap and constraints analysis of wheat production. *Indian Journal of Agricultural Research* **15**(1): 17–20.
- ICAR. 2015. *Front Line Demonstrations: Guidelines and Impact Assessment*. Indian Council of Agricultural Research, New Delhi.
- IGFRI. 2019. *Vision 2030*. ICAR-Indian Grassland and Fodder Research Institute, Jhansi, Uttar Pradesh, India.
- Kumar S, Dixit A K and Singh V. 2020. Yield gap analysis in fodder crops under frontline demonstrations. *The Indian Journal of Animal Sciences* **90**(6): 842–46.
- Kumar R, Singh M and Meena B S. 2018. Economic evaluation of fodder crops under frontline demonstrations. *Forage Research* **44**(2): 120–24.
- Lal R, Meena H R and Sharma P. 2020. Role of FLDs in accelerating adoption of forage technologies. *The Indian Journal of Agricultural Sciences* **90**(5): 911–15.
- Meena M L, Dheeraj R and Singh B. 2016. Effect of improved varieties on fodder sorghum yield. *Range Management and Agroforestry* **37**(1): 65–69.
- Mondal M H. 2011. Causes of yield gaps and strategies for minimizing the gaps in different crops of Bangladesh. *Bangladesh Journal of Agricultural Research* **36**: 469–76. <https://doi.org/10.3329/bjar.v36i3.9274>
- Samui S K, Maitra S, Roy D K, Mondal A K and Saha D. 2000. Evaluation of front line demonstration on groundnut. *Journal of the Indian Society of Coastal Agricultural Research* **18**(2): 180–83.
- Singh R and Chauhan J. 2021. Extension approaches for forage crop intensification. *Indian Journal of Extension Education* **57**(4): 10–15.
- Singh V, Kumar S and Yadav V P. 2019. Performance of fodder sorghum varieties under KVK demonstrations. *Forage Research* **45**(3): 189–93.