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Cluster frontline demonstration on soybean (*Glycine max)*: Learning on sustainability indicators

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ABSTRACT

Enhancing production sustainably in oilseeds has been a challenge for the technologists and policy planners. This study focuses on the efforts made through various technological interventions on farmers' field under Cluster Frontline Demonstration (CFLD) in increasing production of soybean [*Glycine max* (L.) Merr.] crop. A total of 27,069 CFLDs on soybean crop were conducted (2018–22) across the country using improved crop varieties (47) and recommended practices (RP). This study aimed to compare the performance of enhanced soybean varieties over farmers' practices (FP). Most of these CFLDs were carried out using variety KDS-726. Four of these 47 varieties (KDS-726, JS 20-34, JS 20-69, and KDS-753) accounted for approximately 49.5% of the demonstrations. Under RP, the cultivars PS-1225 and PS-1235's showed highest and lowest yielding capacities, respectively. Under RP, the extent of difference in yield between the highest and lowest was 213.4%. All the soybean cultivars grown under RP could result in increasing the yield above FP ranging from 1.65 (PS-1225) to 136.8% (VL Soya-77). Under RP and FP, the cost of cultivation for the various soybean cultivars ranged from ₹30,665 to ₹27,074/ha, respectively. Sikkim Pahenlo Bhatmas-1 (₹79,850/ha) and JS 95-60 (₹58,756/ha) showed the highest net returns while MACS-1407 (₹18,250/ha) and PS-1024 (₹6,630/ha) recorded lowest net returns for RP and FP, respectively. Under RP, SYI (sustainable yield index) ranged from 0.61 (MAUS-158) to 0.99 (MAUS-612) while under FP, it ranged from 0.27 (RVS 2001-4) to 0.99 (JS 97-52). Varieties under RP consistently displayed greater SVI (sustainable value index) values than FP in terms of net returns. The key insight suggested that improved soybean varieties have been instrumental in increasing yield and bridging the yield gap.

Keywords: Cluster Frontline Demonstrations, Extension and technology gap, Sustainable yield index

After the United States, China and Brazil, India is the 4th largest producer of oilseeds in the world, contributing 10% to global production and accounting for nearly 20% of the world's total area. Oilseeds are grown in about 12% of the nation's total cultivated land i.e. 29.17 Mha area, with production of 37.7 Mt and productivity of 1059 kg/ha during 2021–2022 (DA&FW 2022). Following cereals, oilseed crops are the second most significant factor in determining the agricultural economy. In India, oilseeds contribute 10% of the value of all agricultural commodities, and 3% of the country's GDP. The varied agro-ecological conditions in the nation provide a conducive environment for cultivating a wide range of oilseeds. Oilseed production takes place in high-risk areas in India where investment returns are unpredictable. It is primarily grown in arid regions with little or inconsistent rainfall, degraded soil, etc. It has led to significant annual volatility in oilseed production. The previously evolved cultivars had no expected impact on oilseed output. The lack of any technological advancement in the creation of high-yielding varieties (HYVs) of oilseeds exacerbates this poor performance. Additionally, farmers are unwilling to use new cultivars since they need expensive herbicides and fertilizers in high dosages. Thus, the yield levels of the majority of oilseed crops have almost stagnated.

Soybean [*Glycine max* (L.) Merr.] is a unique crop that falls into both the oilseed and legume categories. It holds the top position among oilseed crops globally and accounts for nearly 25% of the world's total oil production. Soybean is often considered to be the potential crop in terms of high-quality protein (40%) and oil (20%). Additionally, soybean supplies many essential nutritional components crucial for human health, including amino acids and lysine, which are deficient in most cereals. This remarkable combination of attributes makes soybean a valuable crop (Basediya *et al.* 2018, Singh *et al.* 2018, Singh *et al.* 2019, Basediya *et al.*

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2020). In India, the majority of soybean is cultivated in Vertisols and adjacent soils, which receives around 900 mm of rainfall during the crop season, with significant regional and seasonal variations. The crop contributed to 21% of the country's total edible oil production and generated ₹5459.50 million in foreign revenue (2016–17) by exporting de-oiled cake (DAC&FW 2018). Despite amazing increase in both area and production, a number of abiotic, biotic and socio-economic problems have caused the average national productivity of soybean to essentially plateau at 1,000 kg/ha (Joshi and Bhatia 2003, Bhatnagar and Joshi 2004, Tiwari 2014).

Due to the enormous imbalance between supply and demand, compels India to import vegetable oil, hence cultivation of oilseed is of utmost importance in the country. In 2021, India imported around 13.35 million tonnes of edible oils worth ₹1,17,000 crore which is 60% of its total requirement. The yield gap between demonstration and farmers practice in soybean was over 22.0% (2016–17). Currently varietal replacement rate (<10 years old varieties) in soybean is 78% over the years, however it needs to be enhanced further. In this backdrop, the interventions of Cluster Frontline Demonstrations on Oilseeds (CFLDs) were made to improve the productivity and receive the direct feedback from the farming community (Jha *et al.* 2020). The limitations and potential of the crop in a particular place are better understood by demonstration in the farmer's field. These displays were shown to be a successful method of introducing the farming community to the most recent research-emerging technologies (Ghintala *et al.* 2018). These demonstrations have raised awareness and inspired the respondents and other farmers to adopt suitable methods for the cultivation of oilseeds (Singh *et al*. 2014). In addition, this effort was also meant to expose the farmers about the productive new soybean varieties along with the recommended package of practices, including production and protection technology. As newer technologies if embraced by the farmers, this can help in replacing the redundant farmers' practices and therefore minimizes technical gap. Considering these in view, this study was carried out with following objectives: (i) assessing the technological and extension gap, and technology index of soybean, and (ii) analyzing the soybean crop varieties based on their sustainable yield parameters utilizing the insights generated from CFLDs

MATERIALS AND METHODS

Study area: The study encompasses agricultural regions across the entire nation where soybean cultivation is prevalent. Since 2018 to 2022, a total of 27,069 Field level demonstrations (FLDs), each covering an area of 0.4 ha, were conducted across the nation. These demonstrations focused on evaluating 47 different soybean varieties in conjunction with the recommended package of agricultural practices (RP), and then compared with farmers' practice (FP). In order to identify the issues in soybean growing areas, a baseline survey was conducted during 2018–22. It was found that the use of low-quality local variety seed, lack of seed treatment, lack of soil testing, an improper sowing technique, and the indiscriminate and imbalanced use of inorganic fertilizers and plant protection chemicals all contributed to the lower crop yield.

Sampling techniques and methods of data collection: Prior to conducting demonstrations on farmers' field, a group meeting was organized to choose the farmers, and the selected farmer received specialized, in-depth instruction on the specific practices of soybean crop. Farmers were given seeds of an improved cultivar and essential inputs in accordance to conduct the demonstrations. The choice of place and farmers for the demonstrations was made in accordance with Choudhary (1999) recommendations. For an improved crop cultivar, all technological interventions were implemented in accordance with the recommended package of practices (Table 1). The impact of technological interventions, including the adoption of improved cultivars and recommended agricultural practices implemented in the fields, where the demonstrations took place, was documented and analyzed. This was covering the specific sites where the demonstrations were conducted. The data on grain yield under different conditions (CFLD-RP and farmers' plot) were recorded to calculate various parameters, such as per cent yield increase, technology and extension gap, and technology index. The data collection has been carried out at the demonstration sites across the nation.

Methods of data analyses: Data were recorded from the farmers' plot where CFLDs were conducted. The per cent yield increase, the technology and extension gap, and the technology index, the grain yield were major parameters to study the technological, economic and sustainability dimensions (Table 2). In the study, the operational definition of the technology index was based on the technical feasibility achieved through the implementation of demonstrations, as described by Ghintala *et al.* (2018). Subsequently, the Extension Gap (EG), Technology Gap (TG) and Technology Index (TI) were computed using the formula recommended by Samui *et al.* (2000) and Yadav *et al*. (2004) as given in following equations (1–4). Performance data were collected, compiled and then compared to draw interpretations and make inferences.

$$\text{Extension gap} = \text{Yield from demonstration} - \text{yield from farmers practice} \quad (1)$$

$$\text{Technology gap} = \text{Potential yield} = \text{Yield from demonstration} \quad (2)$$

$$\text{Incremental returns} = \text{Returns from demonstration} - \text{Returns from farmer's practice} \quad (3)$$

$$\text{Technology index (\%)} = \frac{\text{Potential yield} - \text{demonstration yield}}{\text{Potential yield}} \times 100 \quad (4)$$

By comparing the yield and economic advantages of RP vs FP, the performance of RP was evaluated in terms of sustainable yield index (SYI) and sustainable value index (SVI) (Table 3). The conventional approaches were used to determine the variety-wise SYI and SVI (Singh *et al.* 1990) as given in following equations (5 and 6).

$$SYI = \frac{(\bar{y} - \sigma)}{y_{max}} \quad (5)$$

where $\bar{Y}$, estimated average yield of respective treatment; σ, the standard deviation and y_{max} is the maximum yield of the treatment during a year.

$$SVI = \frac{(NR_{avg} - \sigma)}{NR_{max}} \quad (6)$$

where $\bar{Y}$, estimated average net returns of respective treatment; σ is the standard deviation and NR_{max} is the maximum net returns of the treatment during a year.

The statistical analysis was done using SPSS-statistical software (Version 22.0) (Allen *et al.* 2014).

RESULTS AND DISCUSSION

The results indicated that amongst 47 soybean cultivars, KDS-726 had the highest concentration of FLDs (22.05%), followed by JS 20-34 (14.9%), JS 20-69 (7.13%), KDS-753 (5.42%), RVS 2001-4 (5.42%), CG Soya-1 (4.54%), and NRC-37 (4.19%), with the remaining cultivars accounting for the remaining 36.4%. Soybean growing zones of India are divided into South, Central, West, North, East and North-east zone. The location and number of demonstrations are given in Fig. 1.

Yield variability: In Soybean, during 2018 and 2022, demonstration yield increased by 38.45, 36.33, 32.7, 35.34, and 28.94% (13.61, 14.97, 16.15, 16.0, and 16.41 q/ha) compared to FP (9.83, 10.98, 12.17, 11.18, and 12.73 q/ha), in that order. During the research period, different soybean cultivars had different yielding capacities. Soybean seed yield ranged from 650 to 2427 kg/ha for FP, and from 787 to 2467 kg/ha for RP (Table 2). The 5-year mean seed yield of soybean under the RP was 1568 kg/ha, which was 30.34% higher than the five-year mean yield of FP (1203 kg/ha). The highest seed yield in RP (16.41; 16.15 q/ha) was seen in 2022 and 2020, correspondingly. The PS-1225 cultivar produced the highest yield, which was closely followed by KDS 726, MAUS 162, MACS 1281, and JS 93-05; whereas PS-1235 under RP produced the lowest yield. Under RP, the yield variation between maximum and minimum were separated by a margin of 213.4%. A total of 26 (out of 47) cultivars were demonstrated only once, therefore further parameters were not determined. The entire soybean cultivars tested under RP increased yield over FP by 1.65 (PS-1225) to 136.8% (VL Soya-77). The significant increase in demonstration yield compared to FP over the 5-year period underscores the effectiveness of adopting RP in soybean cultivation, facilitated by CFLDs. This consistent improvement suggests the pivotal role of interventions such as the use of improved cultivars and advanced agricultural techniques. Variations in seed yield between FP and RP, as well as among different cultivars, highlight the impact of agronomic factors and technological advancements on crop performance. The findings reported by Singh *et al.* (2018) and Singh *et al.* (2019) provide ssupport for the study. Due to variations in the environmental conditions present in that year, there was a yearly variation in seed output. The yield of soybean was low in the year 2021 due to untimely and excess monsoon rainfall in major soybean growing areas of India which led to excess moisture stress during critical growth stages of the crop resulting in lower productivity (IMD 2022). It has been observed that the yield gap has effectively narrowed as a result of favourable weather conditions and the widespread adoption of improved cultivars and technologies at farmers' fields through FLDs (Kumar and Meena 2013, Raut *et al.* 2016).

Adoption gap: The assessment of Extension gap (EG), Technology gap (TG) and Technology index (TI) over

Table 1 Details of gap assessment under soybean crop cultivation

Management practices	Farmer’s practices	Demonstrated/recommended practices (CFLD)	Gap
Soil application	No soil treatment	*Trichoderma viride* @5 kg/ha with 250 kg FYM/ha	Absolute
Variety	Local variety	Improved variety JS 20-34	Varietal gap
Seed rate (kg/ha)	100–125	75–80	Excessive usage
Seed treatment	No application	Carbendazim + Mancozeb @3 g/kg; Thiamethoxam @2 g/kg and *Rhizobium Japonicum* @10 g/kg of seed	Absolute
Spacing	No optimum spacing and plant population	30 × 8–10 cm	Partly
Method of sowing	Line sowing by seed drill	Line sowing with seed cum fertilizer drill; ridge and furrow system; broad bed and furrow system	Partly
Nutrient management	Indiscriminate and imbalanced use of fertilizers	Soil test based fertilizer application	Absolute
Weed management	No management/one hand weeding	Imazethapyr @100 g/ha at 18–20 DAS + 1 hand weeding at 40 DAS	Absolute
Plant protection measures	Indiscriminate use of pesticides	Need based IPM and IDM	Absolute
Harvesting	Harvested of over-matured crop	Harvested at right stage based on maturity indices	Absolute

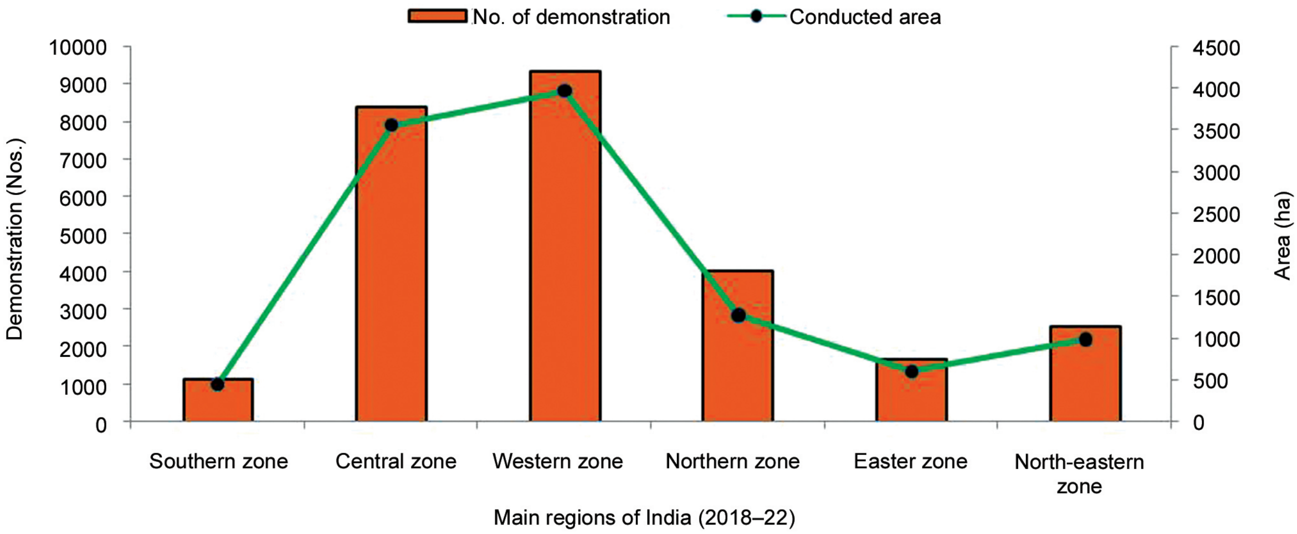

Fig. 1 Number of demonstrations and area covered under CFLD (2018–22).

the 5-year period reveals valuable insights into soybean productivity and adoption trends. The wide range of EG, spanning from 40 to 836 kg/ha, underscores the disparities in extension services and the need for targeted educational interventions to bridge this gap. The substantial TG of 7.83 q/ha highlights the importance of addressing limitations in technology implementation and recommended package of practices to maximize yield potential. The variability in TI, ranging from 9.54–79.83%, signifies the viability of implementing new technologies and underscores the importance of spreading their adoption among farmers. The lack of extension services is an indication that farmers need to be educated and have their skills upgraded in order to adopt new varieties and technologies. This frightening trend of a galloping extension gap will eventually change with the use of the most recent production technologies combined with the usage of suitable high yielding disease and pest tolerant crop varieties. The TG is more important than other metrics because it shows the limitations in the method of technology implementation and shortcomings in the recommended set of packages of practices. Inconsistencies in soil fertility, environmental/climatic conditions, varietal incompatibility, and lack of adoption of improved practices may be the reason for this. Patel *et al.* (2013) observed comparable outcomes in the similar study conducted on frontline demonstrations. TI demonstrates the viability of implementing new technologies and spreading the variety available to farmers. High TI for certain cultivars like MACS-1407 suggests the need for further refinement in technology and practice implementation to optimize performance at farmers' field. The results of the field studies supported the findings of Meena *et al.* (2012) and Patil *et al.* (2015). The observed crop production system had greater viability, as evidenced by the DSB-19's lower TI value. These findings were in accordance with Singh *et al.* (2012), Patel *et al.* (2013) and Singh (2015).

Sustainability indices: The analysis of the data showed that for all 5 years, FP had a higher standard deviation (SD) in production than demonstrations under RP. The greatest values of the SYI and SVI, according to pooled data from 5 years, were discovered under RP in comparison to FP (Table 3). The SYI exhibited values ranging from 0.61 (for MAUS-158) to 0.99 (for MAUS-612) in RP. In contrast, SYI ranged from 0.27 (for RVS 2001-4) to 0.99 (for JS 97-52) in FP. These variations indicate that the minimum assured soybean yield fluctuated between 61% and 99% of the maximum yield under RP and between 27% and 99% under FP. Under RP, the SVI ranged from 0.203 (DSB-19) to 0.922 (MAUS-612) while under FP, the comparable values ranged from 0.178 (JS 20-34) to 0.970 (JS 93-05), respectively. The pooled data analysis showed a notable increase in both the SYI and SVI by 16.68% and 18.16%, respectively, as compared to FP. This suggests that the improved technology exhibits higher sustainability compared to farmer's traditional practices.

Similar tendencies were seen by Chery *et al.* (2014) in intercropping systems based on cotton in semi-arid Vertisols. Higher SD and eventually, higher coefficient of variation in production were shown under FP over the entire trial period. This was due to farmer-to-farmer yield fluctuations were greater than those observed under improved production technologies.

Economic performance: The economic performance of soybean production across different districts in India, assessed through CFLDs (Table 4) and the influence of CFLD on economic viability of soybean in main growing zones of India is represented graphically in Fig. 2. The average cost of cultivating soybean varieties using improved production technologies amounted to ₹30,665/ha, while it was ₹27,074/ha under FP. Amongst varieties, the highest net returns were observed for Sikkim Pahenlo Bhatmas 1 (₹79,850/ha) and JS 95-60 (₹58,756/ha) under RP and FP, correspondingly. On the other hand, lowest net returns were recorded for variety MACS-1407 (₹18,250/ha) under

Table 2 Average yield, technology gap, extension gap and technology index of soybean as affected by recommended and farmer's practices

Variety	Potential yield (q/ha)	Farmer yield (q/ha)	Demo yield (q/ha)	Yield increased (%)	Technology gap (q/ha)	Extension gap (q/ha)	Technology index (%)
AMS-1001	21.73	16.04	18.89	17.68	2.84	2.85	13.09
BSS-2	15.43	9.7	13.33	37.22	2.11	3.63	13.64
CG Soya 01	24.45	9.94	13.73	39.66	10.72	3.79	43.85
DSB 21	28.07	11.59	14.58	25.96	13.49	2.99	48.06
DSB-19	14.39	9.42	13.02	37.08	1.37	3.6	9.54
DSB-34	27	13.59	15.83	16.48	11.17	2.24	41.37
Himsoya	14.62	8.8	12.83	47.4	1.79	4.03	12.27
JS 20-116	21.22	10.38	15.63	54.91	5.59	5.25	26.36
JS 20-29	21.25	12.36	16.02	35.11	5.23	3.66	24.62
JS 20-34	20.52	10.7	13.65	31.87	6.87	2.95	33.46
JS 20-69	18.52	11.64	15.48	34.44	3.04	3.84	16.4
JS 20-98	20.94	10.18	13.72	39.45	7.22	3.54	34.46
JS 21-17	25	7.17	10.82	66.12	14.18	3.65	56.73
JS 80-21	25	12	18.51	54.25	6.49	6.51	25.96
JS 93-05	25	16.65	20.34	21.96	4.66	3.69	18.65
JS 97-52	25	7.96	12.43	64.54	12.57	4.47	50.29
JS 95-60	25.3	12.35	16.89	40.5	8.41	4.54	33.24
JS-335	27	11.86	15.77	34.74	11.23	3.9	41.6
KDS-344	25	15.37	18.88	23.79	6.12	3.52	24.47
KDS-726	31.31	17.15	22.58	32.67	8.73	5.43	27.88
KDS-753	28.43	16.23	19.9	24.35	8.53	3.67	30
MACS 1281	25.19	14.25	20.47	43.65	4.72	6.22	18.74
MACS-1188	24.75	15.19	19.23	27.19	5.52	4.03	22.32
MACS-1407	39	6.5	7.87	21.08	31.13	1.37	79.82
MACS-158	21.25	14.7	18.98	29.24	2.27	4.28	10.68
MAUS 162	30	16.18	20.85	30.81	9.15	4.67	30.5
MAUS-612	30	14.91	18.25	21.22	11.75	3.34	39.18
NRC 37	19.05	13.37	16.56	24.42	2.49	3.19	13.08
NRC-128	22.69	10.9	13.85	21.34	8.84	2.95	38.96
Palam Hara Soya 1	15	8.8	11.99	34.54	3.01	3.19	20.08
Pdkv-Purva	24	14.5	18.5	28.43	5.5	4	22.92
PS-1241	30	9.3	14.92	67.48	15.09	5.62	50.28
PS 1225	29.96	24.27	24.67	1.65	5.29	0.4	17.66
PS 1347	31	8.5	11.25	32.35	19.75	2.75	63.71
PS-1024	17.5	9.11	13.49	49.48	4.01	4.38	22.93
PS-1235	12.5	6.5	7.87	21.08	4.63	1.37	37.04
PS-1368	21.21	11.9	13.28	11.6	7.93	1.38	37.39
RKS-18	16.9	9.3	12.99	41.8	3.91	3.69	23.15
RKS-24	23	13.7	17.59	28.36	5.41	3.89	23.51
RVS 2001-4	22.64	8.16	12.84	59.71	9.8	4.67	43.3
Sikkim Pahenlo Bhatmas 1	16.6	9.4	12.98	112.5	3.62	3.58	21.81
SL 958	22.82	14.5	17.28	19.14	5.55	2.78	24.3
VL Soya-77	19.7	6.11	14.47	136.77	5.23	8.36	26.53
VL Soya 59	26	9.36	13.61	45.04	12.39	4.25	47.65
VL Soya-65	15.42	9.2	10.2	10.87	5.22	1	33.85
VL Soya-89	23.24	9.2	11.5	25	11.74	2.3	50.52
VL Soya-63	27	10.6	15.2	43.4	11.8	4.6	43.7

Table 3 Categorization of varieties based-on sustainable yield index (SYI) and sustainable value index (SVI) under recommended practices (RP)

SYI	Variety	SVI	Variety
>0.9	JS 335, KDS 726, MAUS 162, MAUS 612, NRC 37, RKS 24	>0.9	MAUS 612
0.81– 0.9	DSB-21, JS 95-60, MACS 1188, RVS 2001-4	0.81–0.9	DSB-21, JS 20-34, JS 20-69, JS 335, JS 97-52, KDS 753, NRC 37,
0.71–0.8	CG Soya-1, JS 20-29, JS 20-34, JS 20-69, JS 97-52, Palam hara soya 1	0.71–0.8	-
0.61–0.7	DSB-19, JS 20-98, KDS 753, MAUS 158, RKS 18	0.61–0.7	KDS 726, RKS 18, RKS 24, RVS 2001-4,
0.51–0.6	-	0.51–0.6	CG Soya-1, JS 20-29, JS 95-60, MAUS 158, MAUS 162
<0.5	-	<0.5	DSB-19, JS 20-98, MACS 1188, Palam hara soya 1,

Table 4 Economics of soybean crop production as affected by recommended practices and farmer's practices

Variety	Net returns (₹/ha)		B:C ratio		Incremental net returns (₹/ha)
	Farmer	Demo	Farmer	Demo	
AMS-1001	30113	40023	1.97	2.26	9910
BSS-2	16450	32650	1.60	2.09	16200
CG Soya 01	22648	37759	2.21	2.87	15111
DSB 21	30076	43223	2.43	2.82	13148
DSB-19	34207	55852	2.22	2.73	21645
DSB-34	21000	40352	1.85	2.60	19352
Himsoya	15544	35903	1.43	2.02	20359
JS 20-116	25097	57880	2.26	3.00	32783
JS 20-29	33547	54913	2.51	3.06	21366
JS 20-34	35065	55887	2.00	2.43	20822
JS 20-69	27839	43411	2.23	2.82	15572
JS 20-98	22268	37933	2.11	2.63	15665
JS 21-17	17847	26246	2.24	2.25	8399
JS 80-21	24550	50900	1.81	2.33	26350
JS 93-05	42998	57677	2.19	2.57	14679
JS 97-52	26764	39307	2.31	2.70	12543
JS 95-60	58756	69749	2.46	2.86	10993
JS-335	32580	52753	2.33	2.85	20172
KDS-344	20078	30316	1.73	2.06	10238
KDS-726	49708	74694	2.26	2.79	24986
KDS-753	40076	63215	1.97	2.54	23139
MACS 1281	15575	43771	1.34	1.99	28196
MACS-1188	40005	56434	2.29	2.86	16429
MACS-1407	12375	18250	1.25	1.33	5875
MACS-158	32944	49341	2.04	2.45	16397
MAUS 162	39410	59661	2.28	2.86	20251
MAUS-612	40138	53882	2.16	2.42	13743
NRC 37	29002	41564	2.18	2.50	12562
NRC-128	19330	52153	1.90	2.43	32823
Palam Hara Soya 1	14994	25383	1.83	2.31	10389

Contd.

Table 4 *Contd.*

Variety	Net returns (₹/ha)		B:C ratio		Incremental net returns (₹/ha)
	Farmer	Demo	Farmer	Demo	
Pdkv-Purva	41750	67650	1.99	2.57	25900
PS-1241	27475	56785	1.89	2.61	29310
PS 1225	43151	58673	1.85	2.12	15522
PS 1347	9700	30150	1.39	2.17	20450
PS-1024	6630	39330	1.24	2.14	32700
PS-1235	12375	18250	1.25	1.33	5875
PS-1368	22350	35562	2.17	2.50	13212
RKS-18	13027	28262	1.66	2.28	15235
RKS-24	32951	46564	2.68	3.08	13613
RVS 2001-4	18166	34542	2.01	2.60	16376
Sikkim Pahenlo Bhatmas 1	20500	79850	1.59	3.00	59350
SL 958	37620	42538	2.36	2.21	4918
VL Soya-77	12613	32913	1.44	2.13	20300
VL Soya 59	22370	43710	1.79	2.49	21340
VL Soya-65	9800	25050	1.38	1.97	15250
VL Soya-89	21900	36500	1.52	1.83	14600
VL Soya-63	22610	40460	1.98	2.62	17850

RP and PS-1024 (₹6,630/ha) under FP. The comprehensive average net returns and benefit-cost (B:C) ratio for the RP were ₹45,061/ha and 2.45 as compared to ₹26,510/ha and 1.95 for FP, respectively. The average cost of cultivating soybean varieties under RP surpassed that of FP, indicating higher investment in improved methods. Notably, RP demonstrated higher net returns and B:C ratio compared to FP, underscoring the economic advantages of adopting recommended practices. This improvement in economic performance within demonstration plots can be attributed to the adoption of seed treatment, balanced fertilizer application, timely sowing using mechanical methods, and integrated crop management practices facilitated by CFLDs. The observed increment in returns under RP above FP, alongside increased input costs, further underscores the

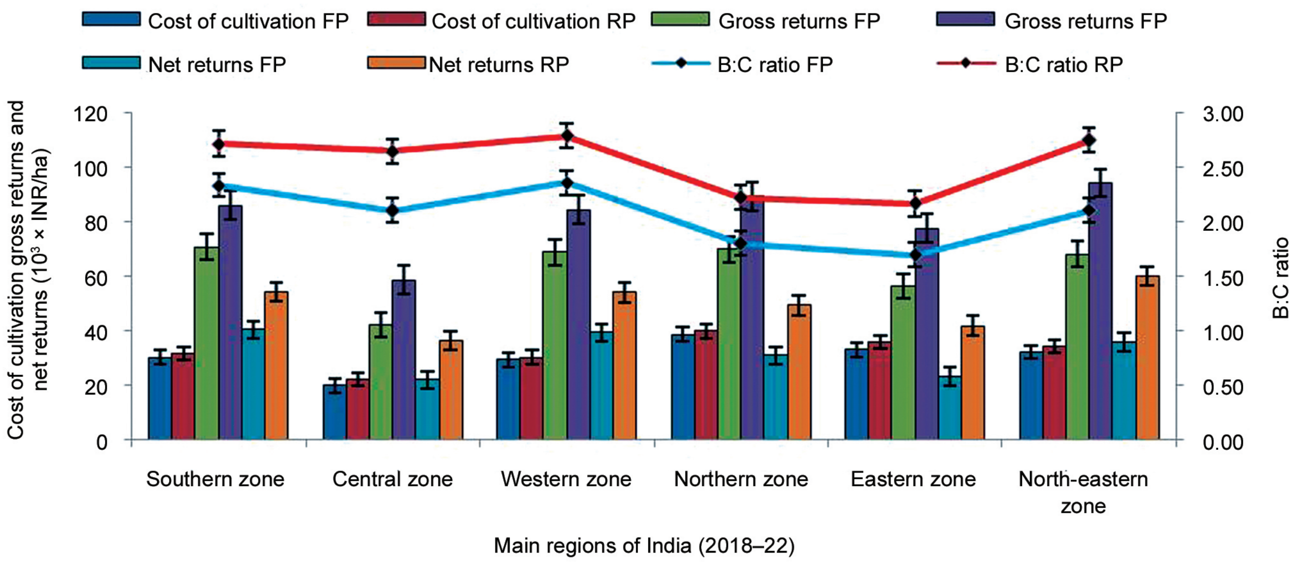

Fig. 2 Effect of CFLD on cost of cultivation, gross returns, net returns and B:C ratio of soybean (5-years average).

economic benefits derived from CFLDs over the five-year period. These findings align with previous research by Hiremath *et al.* (2007) and Hiremath and Nagaraju (2009). The mean of 5 year incremental returns under RP above FP ranged from ₹4918/ha to ₹59350/ha, with an average additional return of ₹18551/ha. The average increased cost of inputs under RP over a five-year period was ₹3591/ha, indicating improved profitability and economic viability of demonstration plots. The higher incremental returns acquired through demonstrations may be attributable to better production technology and consistent monitoring and technical advice from scientists (Lathwal 2010, Singh *et al.* 2012, Patel *et al.* 2013).

Conclusion and policy implications

The key findings suggest that implementation of CFLDs (Cluster Frontline Demonstrations) alongside traditional frontline demonstrations has substantially augmented the scale and reach of agricultural interventions, fostering heightened visibility and resource sharing among farmers. This concerted effort has notably propelled yield enhancement, thereby making a significant contribution to India's food security. Moreover, it has charted a promising trajectory towards bolstering self-sufficiency in the oilseed sector, thus alleviating the burden of imports. To sustain and amplify these gains, it is imperative to perpetuate interventions on a cluster basis and extend robust support to farmers, particularly those with limited resources, by integrating appropriate technologies at the grassroot level promptly.

The success of the CFLDs initiatives underscores the importance of scaling-up and diversifying these efforts across various oilseed crops. It is crucial to strengthen collaboration among stakeholders and enhance knowledge-sharing platforms to facilitate the widespread adoption of novel soybean varieties and advance production technologies. Moreover, targeted capacity-building programmes can be prioritized to strengthen decision making of farmers, particularly those with limited resources, with the necessary skills and knowledge to enable them for adopting good practices. Continuous monitoring and evaluation mechanisms are essential to assess the impact of CFLDs and refine intervention strategies based on empirical evidence. Institutional establishments play a pivotal role in supporting the expansion and sustainability of CFLD initiatives. Adequate resources and funding allocation may facilitate the scaling-up of CFLDs and promote research aimed at developing high-yielding and resilient soybean varieties tailored to diverse agro-ecological conditions. The sustained investment and collaborative efforts from both extension/developmental agencies and institutional establishments are imperative to build upon the success of CFLDs, and advance India's journey towards self-sufficiency in edible oil production, thereby reducing dependence on imports.

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