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RESEARCH PAPER

Impact assessment of cluster frontline demonstrations on soybean yield improvement in farmer's fields

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Abstract: The yield gap between the improved package of practices and the farmer's practice under cluster frontline demonstrations for improving the soybean yield was studied on the fields of 145 farmers of Pune and Satara districts during the *kharif* seasons from 2015 to 2024. The results revealed that the adoption of improved practices for soybean cultivation produced an average seed yield of 2806 kg/ha, whereas the farmer's practice produced 2357 kg/ha. The per cent increase in yield with improved practices over farmer's practice was 19.05%. The extension gap and technology index ranged between 338 to 562 kg/ha and 1.79 to 28.46%, respectively. Similarly, economic analysis showed that the average net returns and benefit-cost ratio were higher under the improved practice (₹ 72,812/- per ha and 2.86:1, respectively) as compared to farmer's practice (₹ 57,253/- per ha and 2.56: 1, respectively). Likewise, with an average additional cost of ₹ 2246/- per ha, the additional average net returns of ₹ 15,559/- per ha were obtained with the adoption of improved varieties and production technologies under the improved practice of soybean cultivation. The average break-even yield under the improved practice (980 kg/ha) was higher than the farmer's practice (920 kg/ha), while the average break-even cost was lower under the improved practice (₹ 13.71/- per kg) compared to the farmer's practice (₹ 15.36/- per kg).

Key words: Break-even cost, Break-even yield, Extension gap, Sustainable yield index, Technology gap, Technology index

Introduction

Soybean [*Glycine max* (L.) Merrill] is one of the important oilseed and legume crops, contributing 25% of the global edible oil. Its seed contains protein (40-42%), oil (19-21%) and essential amino acids. Due to its multiple uses, it has occupied an important place in the existing farming systems. Soybean crop play an important role in sustainable agriculture by enriching the soil health by fixing atmospheric nitrogen (80-100 kg/ha), and the tap root system of this crop has made it more suitable for its cultivation under rainfed conditions. In India, soybean is cultivated in an area of about 11.8 million hectares with an average production of 11.87 million metric tons with productivity of 1 metric ton per hectare (SPOA, 2023). India is the world's fifth largest soybean producer after Brazil, USA, Argentina and China. However, the productivity of soybean in India (1 t/ha) is less than that of the world's (3.01 t/ha) average productivity. In India, Maharashtra is the second largest producer of soybean after Madhya Pradesh. The area under soybean in Maharashtra state is 4.5 million hectares, which contributes 33-35% of the soybean area in the country, with an average productivity of 1028 kg/ha (SOPA, 2023).

The diversified and favorable climatic conditions of Maharashtra gives a scope for improving soybean productivity by promoting its growth with suitable soils and farmer as well as industrial acceptability. However, there is a big gap between the yield potential of the varieties and actual productivity in the farmer's field. Efforts are being made by policymakers, government, NGOs and scientists, to bridge this gap. Though, there are several factors responsible for the low productivity of soybean, which can be mainly categorized as climatic factors, unavailability of improved varieties, poor soil, crop and post-harvest management, in a general and slow pace of technology transfer and adoption, lack of knowledge on improved varieties for cultivation and its suitability, lack of awareness of improved crop production and management techniques, imbalanced fertilizer use, lack of knowledge on plant protection measures and agrochemicals and their use (Dupare *et al.,* 2019). To overcome this and facilitate the effective dissemination of improved crop production technologies of the soybean crop on farmer's fields through a cluster approach of demonstrating the improved technologies, based on the principle of learning by doing, seeing and believing, CFLDs is one of the government initiatives under the ICAR and are conducted at farmer's fields under the direct supervision of scientists, with the major objective of demonstrating the production potential of improved production technology developed through research for different agro-climatic regions on location-specific basis, under real farm situations (Dupare *et al.,* 2019; Sharma and Singh, 2024). Front-line demonstrations (FLDs) aim to increase production and productivity by supplying the required inputs and scientifically proven production technology through expert scientists. The FLDs proved to be the most effective tool in demonstrating and disseminating the latest research technologies developed among the farmers (Gautam *et al.,* 2007). Improved technology includes new high yielding varieties, recommended doses of nutrients with combination of bio fertilizers, plant protection measures, weed control measures and improved crop management practices. To transfer the improved soybean cultivation technologies among the rural masses for impactful adoption, understanding the gaps in production technology and gathering information for formulating policies to overcome these gaps, a break-even analysis of price and soybean yield for profitability, the present study was undertaken.

Material and methods

The present study was carried out by Agharkar Research Institute, Pune, (MS), India, during 2015-2024 for ten consecutive years in the farmer's fields of 53 villages of Pune and Satara districts in Maharashtra state. A total of 145 (Table 1) cluster frontline demonstrations (CFLDs) on soybean were planned under the ICAR All India Coordinated Research Project on Soybean as Frontline Demonstrations on Soybean at Farmers fields to demonstrate the impact of recently released improved soybean varieties, their production technologies and their overall performance over the old varieties and farmer's traditional practice of soybean cultivation. The beneficiary farmers for CFLDs were randomly selected from the villages of Pune and Satara districts, covering a 58 ha area with a plot size of 0.40 ha under each demonstration. Additionally, the farmers with an additional 0.40 ha area of soybean or adjoining farmers with 0.40 ha area of soybean crop under their management practices were selected for comparison as a farmer's practice. To maximize the impact of the demonstrated technologies, a demonstration site in a cluster was chosen based on its accessibility, farm size, field layout, soil type and fertility status, as suggested by Bhartiya *et al.* (2017). From 2015 to 2024, prior to conducting the CFLDs, a survey was carried out to understand the constraints in soybean production in the targeted areas to decide the strategy for improving soybean productivity and disseminating new varieties and production technologies among the farming community through pilot demonstration. It was followed by group meetings in the selected villages and specific skill training was imparted to the selected farmers regarding the adoption of improved technologies and varieties to improve soybean productivity (Venkattakumar *et al.,* 2010). Farmers from various social strata in the villages were selected to ensure the distribution of benefits across the community. The CFLDs were planned to deliver the full package of practices comprising the distribution of improved varieties *viz*., MACS 1188, MACS 1281, RKS 18, MACS 1407, MACS 1520, MACS 1460 and MACSNRC 1667, seed treatment and sowing, nutrient management, weed management, pest and disease management, on which farmers had lack of knowledge. A recommended dose of fertilizer (RDF) of 20 kg N, 80 kg P_2O_5, 20 kg K_2O and 30 kg Sulphur per ha were supplied through DAP, SSP and MOP at the time of sowing using seed-cum-fertilizer seed drill. Seeds were treated with Thiram 3 g/kg of seed and inoculated with *Bradyrhizobium japonicum* @ 5 g/kg of seed and phosphorus-solubilizing bacteria @ 5 g/kg of seed. After inoculation, seeds were dried in the shade and sown at a spacing of 45 cm between the rows and 5-7 cm between the plants. All the crop production technologies under improved practice (IP) and farmer's practice (FP) are presented in Table 1. Regular monitoring of the demonstration plots was done by scientists and technical staff and delivered real time crop advisories to ensure healthy crop growth during the crop season. Field days, short training sessions on farms, and Farmer's mela were organized to interact with beneficiaries and other farmers, fostering productive interactions to maximize the benefits of the demonstration and ensure the successful implementation of CFLDs for significant impact. The data on production and economics under FP and IP were collected after the completion of every crop cycle and analyzed to express it in terms of a per cent increase and determination of various indices. Economics in terms of cost of cultivation (₹ ha^{-1}), gross returns (₹ ha^{-1}), net returns (₹ ha^{-1}), benefit: cost ratio (BCR), incremental cost (₹ ha^{-1}), incremental net returns and incremental benefit: cost ratio (IBCR) were worked out using the prevailing market price of inputs and soybean grain (Bhartiya *et al.,* 2017

Table 1. Details of soybean cultivation under improved practice and Farmer's practice

Particulars	Frontline demonstration	Farmer's practice
Varieties used	MACS 450, MACS 1188, MACS 1281 and RKS 18	JS 335 and seeds of private companies
Seed rate	65 kg/ha	75-80 kg/ha
Seed inoculation and seed treatment	i) Seed treatment with Carbendazim 50 WP ii) Seed inoculation with biofertilizers (*Rhizobium* and PSMs)	No seed inoculation or seed treatment followed
Sowing spacing	45 cm x 5-7 cm	22-30 cm x 5 cm
Plant population	Optimum	More or less than optimum
Manures and Fertilizers	FYM: 5-8 t/ha RDF: 20:80:20 NPK kg/ha; 30 kg Sulphur per ha	FYM: 3- t/ha Fertilizers- Not as per RDF of the crop, excess use of N fertilizers
Weed control	Pre-emergence application of Pendimethalin @ 1 *a.i* kg/ha1 hand weeding/1 hoeing	No use of herbicides to control weeds No or 1-2 hand weeding
Insect-pest control	Use of Pheromone traps to control *Spodoptera litura* Sprays of Dimethoate 30 EC 0.5 l/ ha or Rynaxypyre 20 SC @ 100 ml /ha or Quinalphos 20 EC 1.5 l/ha	No use of pheromone traps excessive use of insecticides
Irrigation management	Irrigations at the critical growth stages of crop to avoid moisture stress	Mainly dependence on rainwater hence no irrigation as per the critical growth stages of crop
Harvesting, threshing *etc*.	Harvesting at proper maturity stage at 12-14% grain moisture	Irrespective of grain moisture only on the visual colour of leaves.

and Billore *et al.,* 2020). The extension gap, technology gap and technology index (%) were worked out as per the formula suggested by Samui *et al.* (2000).

Incremental benefit: cost ratio (IBCR)= Additional net returns (₹ /ha) / Additional cost (₹ /ha)

Technology gap = Potential yield - Demonstration yield

Extension gap = Demonstration yield - Farmer's yield

Technology index = (Potential yield - Demonstration yield) / Potential yield) x 100

To determine the values at which price, production and output were adequate to cover specific costs, the break-even analysis was used suggested by Chambers *et al.* (1979), Baute *et al.* (2002) and Cook *et al.* (2012). Similarly, the sustainable yield index (SYI) of the varieties was determined as per the standard formula given by Singh *et al.* (1990).

SYI / SVI = Y/V-SD / Y max.

Where Y/V is the estimated average yield/net return of practice over a year (study period), SD is the standard deviation, and Y max is the observed maximum yield/maximum net return during the study period.

Results and discussion

Effect on seed yield under CFLDs: The pooled results of cluster frontline demonstrations (CFLDs) of soybean over ten years showed that the soybean seed yield ranged from 2125 to 3250 kg/ha under improved practice, whereas it ranged from 1875 to 2750 kg/ha under farmer's practice (Table 2). Among the varieties, the maximum average yield (3125 kg/ha) was recorded with MACS 1520 under improved practice, while the average minimum yield was recorded with RKS 18 (2100 kg/ha) under farmer's practice (Table 3). The seed yield variation might be due to variability in soil fertility and environmental factors. Singh *et al.* (2013) studied the variation in yield over the years due to variability in edaphic and climatic factors. The yield gap between the improved and farmer practices ranged from 338 to 562 kg/ha. The average per cent increase in seed yield was 19.05% due to improved practice over farmer's practice. The highest per cent increase in seed yield was observed with MACSNRC 1667 (22.22%), while the least was with RKS 18 (16.10%). Higher seed yield under improved practice might be due to the sowing of improved varieties like MACS 1188, MACS 1281, MACS 1460, MACS 1407, MACS 1520, RKS 18 and MACSNRC 1667, having high adaptability and yield potential, optimum seed rate, seed inoculation before sowing, line sowing at recommended spacing, balanced nutrition through FYM and inorganic fertilizers, timely management of weeds, pest and diseases and application of protective irrigation. These findings support the yield increase due to the adoption of the improved practice over the farmer's practice, which was earlier reported by Tomer *et al.* (2003) and Dupare *et al.* (2019). In the present study, the frontline demonstrations impacted the soybean farming community as they were motivated by improved cultivation technologies. Also, results indicate the positive effect of CFLDs over existing traditional soybean production practices with increased yield. In earlier studies, yield enhancement due to the adoption of improved technology, especially the use of improved varieties, has been reported in FLDs by various workers (Meena *et al.,* 2012; Billore *et al.,* 2020).

Yield gap: The average yield gap under improved practice and farmer's practice was less in variety RKS 18 (338 kg/ha) than the rest of the varieties and higher in MACS 1520 (562 kg/ha).

Table 2. Soybean yield (kg/ha) under improved practice and farmer's practice in CFLDs during 2015-2024

Varieties	Year																			
	2015		2016		2017		2018		2019		2020		2021		2022		2023		2024	
	IP	FP	IP	FP	IP	FP	IP	FP	IP	FP	IP	FP	IP	FP	IP	FP	IP	FP	IP	FP
MACS 1188	2450	2125	2678	2391	2933	2438	2530	2025	2597	2126	2996	2411	2911	2489	2808	2333	-	-	2250	2000
RKS 18	2131	1875	2625	2250	2125	1938	2375	1875	2995	2410	2375	2250	-	-	-	-	- -	-	-	
MACS 1281	3125	2688	2511	2223	3167	2333	2688	2219	3247	2602	3245	2600	3085	2745	2850	2500	-	-	-	-
MACS 1460	-	-	-	-	-	-	-	-2376	2249	2596	2125	2867	2450	3250	2750	2361	2026	2861	2431	
MACS 1407	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3125	2750	2750	2250	-	-
MACS 1520	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3125	2563	-	-	-	-
MACSNRC 1667	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2750	2250	-	- -	-	-

-CFLDs not conducted, IP: Improved practice, FP: Farmer's practice

Table 3. Yield increment in IP over FP and evaluation of the varieties in CFLD based on different gaps

Varieties	No. of farmers	IP(Yield kg/ha)	FP (Yield kg/ha)	Yield gap (kg/ha)	% Increase over FP	Potential yield (t/ha)	Technology gap (kg/ha)	Extension gap (kg/ha)	Technology index (%)
MACS 1188	55	2684	2260	424	18.76	3000	316	424	10.55
RKS 18	10	2438	2100	338	16.10	3300	862	338	26.13
MACS 1281	38	2990	2489	501	20.13	4000	1011	501	25.26
MACS 1460	37	2719	2339	380	16.23	3800	1081	380	28.46
MACS 1407	2	2938	2500	438	17.50	3900	963	438	24.68
MACS 1520	2	3125	2563	562	21.93	3200	75	562	2.34
MACSNRC 1667	1	2750	2250	500	22.22	2800	50	500	1.79
Overall mean	145	2806	2357	449	19.05		623	449	17.03

IP: Improved practice, FP: Farmer's practice

The higher yield gap under CFLDs is attributed to soybean crop grown as rainfed, poor nutrient management, lack of insect-disease management, use of old varieties and traditional methods of sowing. This indicates an urgent need for an implimentation of the scientifically proven technologies and recommendations of soybean cultivation to bridge the yield gap arising in potential and demonstration yield (Vedana *et al.*, 2007) and the quantification of the yield gaps perhaps be a key strategy to understand such yield gap, its cause and may help in focusing the research and policy for bridging the yield gaps sustainably (Bhartiya *et al.,* 2017).

Technology gap: The difference between potential yield and demonstration plot yield is referred to as the technology gap. In the present study, the technology gap (Table 3) ranged from 50 to 1081 kg/ha for the soybean varieties under study. The mean technology gap was 623 kg/ha, which suggests still there is a gap in technology demonstration, preventing beneficiary farmers from benefitting from varietal potential output (Naveen *et al.,* 2024). The highest technology gap was recorded in variety MACS 1460 (1081 kg/ha), followed by MACS 1281 (1011 kg/ha) and MACS 1407 (963 kg/ha) and the lowest was with MACSNRC 1667 (50 kg/ha) followed by MACS 1520 (75 kg/ha). The wider technology gap may be attributed to variability in the fertility of the soil, local climatic conditions, varietal differences and variation in crop management (Singh *et al.,* 2013; Undhad *et al.,* 2019; Jadhav *et al.,* 2023). Hence, precise application and site-specific recommendations are necessary to lower the technology gap in soybean.

Extension gap: The difference between the yield of the demonstration plot (improved practice) and the farmer's practice is termed as an extension gap. The data presented in Table 3 revealed that the extension gap ranged from 338 to 562 kg/ha, with an average of 449 kg/ha. The highest average extension gap was recorded in MACS 1520 (562 kg/ha), while the least was with RKS 18 (338 kg/ha). The wide extension gap in the study shows the unawareness among the farmers for the new and improved production technologies of soybean cultivation (Vedana *et al.,* 2007; Kumar *et al.,* 2019). The increased values of the extension gap signify the need to educate farmers through extension measures and to popularize the adoption of improved technologies of soybean cultivation to increase production and reverse this trend of the wide extension gap (Sharma and Singh, 2024). Farmers' reluctance to adopt improved production technologies contributes to the widening of the extension gap (Vedana *et al.,* 2007); hence, educating the farmers through various extension education tools for increasing awareness and adoption of the improved production technologies of soybean is necessary.

Technology index: The technology index indicates the feasibility of evolved technology in the farmer's field. The lower the value of the technology index, the greater the feasibility of the technology (Jeengar *et al.,* 2006). The difference in the technology index ranging from 1.79% to 28.46% in the present study might be due to soil fertility status, weather conditions, variation in management practices and pest attacks. The lowest value of the technology index of soybean variety MACSNRC 1667 (1.79%) and MACS 1520 (2.34%) showed the increasing feasibility of these recently released and improved varieties as well as improved production technologies in the demonstrations, which can be adopted easily by the farmers in the locality in future for improving the soybean yield.

Table 4. Economic analysis of the soybean varieties under CFLDs

Varieties	Gross returns (₹ /ha)		Net returns (₹ /ha)		Cost of cultivation (₹ /ha)		B: C ratio	
	IP	FP	IP	FP	IP	FP	IP	FP
MACS 1188	94571	79826	59311	46892	35260	32934	2.68	2.41
RKS 18	76625	66030	44696	36185	31929	29845	2.39	2.21
MACS 1281	101021	84496	66211	52123	34809	32410	2.89	2.60
MACS 1460	110234	94921	71919	59360	38314	35561	2.87	2.66
MACS 1407	132188	112500	88594	70550	43594	41950	3.03	2.68
MACS 1520	140625	115313	97352	74713	43273	40600	3.25	2.84
MACSNRC 1667	123750	101250	81602	60950	42148	40300	2.94	2.51
Overall mean	111288	93476	72812	57253	38475	36229	2.86	2.56

IP: Improved practice, FP: Farmer's practice

Table 5. Economic analysis and break-even cost and break-even yield of soybean under CFLDs

Varieties	Incremental cost (₹ /ha)	Incremental net returns (₹ /ha)	Incr. B: C ratio	Break-even cost (₹ /kg)		Break-even yield (kg/ha)		SYI	
	IP	IP		IP	FP	IP	FP	IP	FP
MACS 1188	2628	13175	5.50	13.14	14.57	1001	932	0.78	0.81
RKS 18	1892	6175	3.06	13.10	14.21	1016	949	0.70	0.75
MACS 1281	2405	14062	5.78	11.64	13.02	1030	955	0.88	0.90
MACS 1460	2958	14119	5.62	14.09	15.21	945	876	0.79	0.84
MACS 1407	1644	18044	24.09	14.84	16.78	969	932	0.86	0.91
MACS 1520	2673	22640	8.47	13.85	15.84	962	902	0.92	0.93
MACSNRC 1667	1848	20652	11.18	15.33	17.91	937	896	0.80	0.81
Overall mean	2293	15552	9.10	13.71	15.36	980	920	0.82	0.85

IP: Improved practice, FP: Farmer's practice, Incr.: Incremental and SYI: Sustainable yield index

Economic analysis: An economic analysis of the frontline demonstrations considering the input and output prices of the commodities that prevailed during the study period was presented in Table 4. The results showed that the average cost of cultivation was comparatively higher (₹ 38,475/- per ha) under improved practice compared to farmer's practice (₹ 36,229/- per ha), attributed to the additional inputs and following all the recommended practices required for obtaining the high yield. The demonstration plots containing improved practice fetched the higher average gross returns (₹ 1,11,288/- per ha), net returns (₹ 72,812/- per ha) and B: C ratio (2.86: 1) compared to the farmer's practice over the study period. Whereas, under farmer's practice, the average gross returns were ₹ 93,476/- per ha, average net returns were ₹ 57,253/- per ha and the B: C ratio was 2.56: 1 over the study period. Adoption of improved production technologies under improved practice gained average additional net returns of ₹ 15,559/- per ha over farmer's practice, with an average additional cost of cultivation of ₹ 2246/- per ha and an average incremental benefit-cost ratio of 9.10: 1 (Table 5). Similar results were reported by Raju *et al.* (2015). An increase in net returns due to the adoption of improved practice was an average of 27.17% over the farmer's practice.

Break-even yield, cost and sustainable yield index: Based on the cost of inputs, cost of cultivation and selling price of produce prevailed in the market, the break-even yield was worked out (Table 5). The break-even yield analysis shows potential profit losses if yields and premiums fall below the critical thresholds (Billore *et al.*, 2020). In the present study, the average break-even yield varied from 937 kg/ha (MACSNRC 1667) to 1030 kg/ha (MACS 1281) under improved practice. The average soybean yield needed to break even was 980 kg/ha to receive positive returns under improved soybean production technology. Whereas, in farmer's practice, the average break-even yield varied from 876 kg/ha (MACS 1460) to 955 kg/ha (MACS 1281). The break-even yield of 980 kg/ha showed profitability in soybean cultivation under improved technology. Similar results were reported by Mayata *et al.* (2014) and Billore *et al.* (2020). The average break-even cost per kg of the produce ranged from ₹ 11.64/- (MACS 1281) to ₹ 15.33/- (MACSNRC 1667) with the overall mean of ₹ 13.71/- per kg under improved practice, while it ranged from ₹ 13.02/- (MACS 1281) to ₹ 17.91/- (MACSNRC 1667) with an average of ₹ 15.36/- per kg under farmer's practice. It indicates that the BEY of the recently improved varieties adopted by farmers under improved practice were higher than local/old varieties used under farmer's practice. However, the BEC of the improved varieties under improved practice was lower than that of the local/old varieties used under farmer's practice. Similar results were reported by Dupare *et al.* (2019) and Billore *et al.* (2020). The average sustainable yield index (SYI) showed a variation from 0.70 (RKS18) to 0.92 (MACS 1520) under improved practice, while it was 0.75 (RKS 18) to 0.93 (MACS 1520) under farmers practice, indicated that minimum guaranteed soybean yield varied from 70 to 92% of the maximum yield under IP and 75 to 93% under FP.

Conclusion

In the present study, the improved practice resulted in an average of 19.05% higher yield over the farmer's practice, with an average additional cost of ₹ 2246/- per ha, which gave additional net returns of ₹ 15,559/- per ha with an average incremental benefit-cost ratio of 9.10:1. Further, the break-even yield of the recently improved varieties and production technologies adopted by farmers under improved practice was found higher than local and/or old varieties used under farmer's practice, while the break-even cost was lower. Hence, the adoption of the improved varieties and production technologies of soybean helps in narrowing the yield gap and thus improves the soybean yield in farmers' fields and their income.

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