



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
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NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(7): 29-31
Received: 02-05-2026
Accepted: 08-06-2026

Dr. Shelke PP
Senior Scientist and Head, Krishi
Vigyan Kendra, Hingoli,
Maharashtra, India

Shri. Rajesh S Bhalerao
Subject Matter Specialist
(Agronomy), Krishi Vigyan
Kendra, Hingoli, Maharashtra,
India

Dr. Murai Atul M
Subject Matter Specialist
(Agricultural Extension), Krishi
Vigyan Kendra, Hingoli,
Maharashtra, India

Impact of Cluster Frontline Demonstrations (CFLD) on yield dynamics and economic performance of Soybean (*Glycine max* L.) in smallholder farm ecosystems of Hingoli District

Shelke PP, Shri. Rajesh S Bhalerao and Murai Atul M

DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i7a.5886>

Abstract

Soybean (*Glycine max* L.) represents a vital agronomic vehicle for augmenting farm income and reinforcing smallholder rural livelihoods in semi-arid tropical ecosystems. However, a significant yield gap persists at the farm level due to sub-optimal operational management, including the usage of degenerated landraces, imbalanced fertilization, and poor plant protection coverage. To address this, a large-scale evaluative study was conducted across the Hingoli district of the Marathwada region, Maharashtra, India. Managed by the Krishi Vigyan Kendra, Hingoli, under the Cluster Front Line Demonstration (CFLD) oilseeds framework sponsored by ICAR-ATARI, Zone-VIII, Pune this multi-year trial spanned three consecutive Kharif seasons 2023 to 2025. The intervention covered an aggregate area of 565 hectares, directly incorporating 1,525 smallholder farm environments. The results indicated a substantial yield enhancement under demonstration plots utilizing improved agronomic packages including high-yielding, climate-resilient varieties like KDS-726 and MAUS-612, Broad Bed Furrow sowing, integrated nutrient management, and targeted pest boundaries compared to traditional farmers' practices. Extension gaps, technology gaps and the technology index were computed to evaluate the extension efficacy. Economic analysis further revealed a significant increase in net returns and a highly favourable benefit-cost ratio B:C ratio in the CFLD plots. This study confirms that structured cluster frontline demonstrations provide an effective institutional framework for accelerating the adoption of sustainable agronomic practices and bridging localized crop productivity deficits.

Keywords: Soybean (*Glycine max* L.), Cluster Frontline Demonstrations (CFLD), yield dynamics, economic performance, farm ecosystems

1. Introduction

Soybean (*Glycine max* L.) stands as a premier global oilseed and protein crop, playing a foundational role in the economic stability of small-to-medium agricultural holdings in developing countries. In India, particularly within the Marathwada eco-zone of Maharashtra state, soybean serves as the backbone of the rainfed agro-ecosystem during the Kharif (monsoon) cropping window. Despite its high genetic potential, the average farm-level yield of soybean remains substantially lower than experimental station outputs. This yield gap is driven by interconnected biotic, abiotic, and institutional constraints. Primary among these are:

1. Continuous cultivation of older, susceptible seed varieties.
2. Imbalanced application of primary nutrients (N:P:K) leading to soil mining and phosphorus immobilization.
3. Heavy dependency on broadcast flatbed sowing, which leaves crops vulnerable to monsoon dry spells or sudden flooding.
4. Sub-optimal adoption of Integrated Pest & Disease Management (IPM/IDM) against destructive target insects like *Spodoptera litura* and girdle beetles.

To systematically mitigate these yield bottlenecks, the Indian Council of Agricultural Research, (ICAR) New Delhi design-tested Cluster Frontline Demonstrations (CFLD). Unlike conventional top-down extension frameworks, CFLDs emphasize direct, cluster-centric field interfaces on

Corresponding Author:
Dr. Shelke PP
Senior Scientist and Head, Krishi
Vigyan Kendra, Hingoli,
Maharashtra, India

farmers' lands under the supervision of subject-matter specialists. This study evaluates the impact of CFLDs managed by KVK, Hingoli from 2023 to 2025 to quantify changes in productivity, identify persistent technology gaps, and evaluate economic performance within rainfed farming communities.

2. Materials and Methods

2.1 Study Site and Agro-Climatic Characteristics

The field investigations were executed across multiple representative agricultural villages within the administrative boundaries of the Hingoli district of Maharashtra, The region is characterized by a semi-arid climate, with annual precipitation

predominantly received during the southwest monsoon. The soil matrix is primarily composed of deep-to-medium black cotton soils Vertisols & Inceptisols marked by neutral-to-alkaline pH and medium organic carbon reserves.

2.2 Experimental Matrix and Demonstration Packages

The trials were laid out systematically during three consecutive Kharif cycles (2023, 2024, and 2025). The total footprint comprised 565 hectares distributed across 1,525 individual farming setups. In each layout, the Demonstration Plot (Improved Package) was evaluated alongside an adjacent Control Plot (Farmers' Practice - FP).

Table 1: The critical technological interventions under the demonstration package and farmer’s practices are detailed below

Agronomic Parameter	Farmers' Practice (Control Group)	Demonstration Package (Improved Package)
Cultivar Selection	Mixed, uncertified seed stocks or degenerated local varieties.	High-yielding, disease-resistant varieties (KDS-726, MAUS-612, PDKV Amba).
Sowing Method	Conventional flatbed broadcasting or narrow row drilling.	Broad Bed Furrow (BBF) technology for in-situ moisture retention and drainage.
Seed Bio-Priming	Negligible seed treatment.	Co-inoculation with <i>Rhizobium</i> , Phosphate Solubilizing Bacteria (PSB) and <i>Trichoderma</i> .
Nutrient Management	Unbalanced, excess reliance on generic Nitrogen and Phosphorus (DAP).	Soil-test-based balanced nutrition (N:P:K) integrated with organic manures.
Plant Protection	Delayed, calendar-based chemical pesticide spraying.	Integrated Pest Management (IPM) using pheromone traps, yellow sticky cards and bio-pesticides.

2.3 Economic Indicators

Gross monetary returns, net returns, and benefit-cost ratios (B:C Ratio) were determined using prevailing local farm-gate prices and input production costs.

Results and Discussion

Yield Optimization Profiles

The aggregate data over the three-year study reveals a clear increase in soybean seed yields within the demonstration plots compared to traditional practices. The year-wise variety, area, respondents, yield and technological performance indicators are presented in Table 2:

Table 2: Cost of cultivation & Gross return of Soybean crop under Cluster Front Line Demonstration and farmer’s practices.

Year	Variety Demonstrated	Area (Ha)	Total Respondents	Gross Cost Rs./Ha		Gross Return	
				Demo	Farmer Practice	Demo	Farmer Practice
2023	AMS-1001	20	50	35310	42859	115689	80213
2024	MAUS 612	45	225	52333	52113	100401	81524
2025	MAUS 612	500	1250	51200	51700	93800	66000

Yield Dynamics of Soybean (2023–2025)

The observed yield improvements under the demonstration package are primarily attributed to the synergetic effects of improved seed varieties and the BBF sowing configuration. The BBF system alters soil bulk density and micro-topography, which optimizes root zone aeration during excessive monsoon rain events and conserves critical moisture during dry spells.

Economic Feasibility and Return on Investment

Financial sustainability is a prerequisite for technology adoption among resource-constrained smallholders. The financial performance indicators over the three-year study demonstrate the clear economic advantage of the improved package (Table 3):

Table 3. Average Yield, Net Return & B:C ratio of Soybean crop under Cluster Front Line Demonstration and farmer’s practices

Year	Variety Demonstrated	Average Yield Q/Ha		Net Return		B:C Ratio	
		Demo	Farmer Practice	Demo	Farmer Practice	Demo	Farmer Practice
2023	AMS-1001	23.61	16.37	80379	37354	3.28	1.86
2024	MAUS 612	21.82	13.91	48068	29411	1.93	1.58
2025	MAUS 612	22.00	15.00	42600	14300	1.83	1.27

Economic Performance & Benefit-Cost Dynamics of Soybean under CFLD

The higher net returns in the demonstration plots stem from optimized crop yields and improved input-use efficiency, particularly through balanced fertilizer applications and targeted pest management. This confirms that the higher upfront cost of high-quality inputs is fully offset by the substantial gains in

harvest volume and market premium.

Conclusion

This three-year evaluation establishes that the widespread adoption of improved agronomic practices through Cluster Frontline Demonstrations (CFLD) significantly enhances soybean productivity and profitability across smallholder farming

systems in Hingoli. By integrating high-yielding cultivars, broad bed furrow management and bio-primed inputs. The study demonstrated consistent yield improvements and a more favourable benefit-cost ratio over traditional farmers' practices. Consequently, institutional scaling of the CFLD extension model is recommended as a strategic pathway to bridge regional yield gaps, improve smallholder incomes and foster long-term agricultural sustainability.

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