SWITCH ON FOUNDATION

Sustainable Pathways in Rice Cultivation: Multi-Location Kharif 2025 Comparative Study

About The Organisation:

SwitchON Foundation (regd. as Environment Conservation Society) was established in 2008 to catalyze the adoption of sustainable technologies and practices, working at the intersection of climate-resilient agriculture, clean energy, green livelihoods and skills. With a dedicated team of **175+ members**, we operate across 8 states in India, empowering communities with climate-smart solutions. Through sustainability and innovation, we are committed to transforming **10 million lives**, ensuring that love and action for the Earth lead to better livelihoods, improved well-being, and a thriving planet for all.

As part of SwitchON Foundation's interventions, multi-location Kharif paddy trials in West Bengal assessed the performance of INM and IPM practices against conventional farming. Key growth, yield, and pest parameters were recorded to evaluate productivity and input-use efficiency. The trials generated evidence supporting sustainable, climate-resilient paddy cultivation.

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EXECUTIVE SUMMARY

Multi-Location Kharif Rice Trial 2025 | West Bengal | SAP vs. Conventional Agricultural Practices

The Report presents findings from a 20-plot, five-cluster, multi-location farmer-managed trial conducted during *Kharif* 2025 in West Bengal, comparing Sustainable Agricultural Practices (SAP) with Conventional Practices (CONV) in smallholder rice systems. The study was designed to generate robust field-level evidence on agronomic performance, cost dynamics, and economic viability under real farming conditions.

While CONV recorded higher plant height (8–9 cm), largely driven by synthetic nitrogen inputs, SAP demonstrated superior crop productivity indicators, particularly in effective tillering (+2.2–2.5 tillers per plant), reflecting improved soil biological activity and rhizosphere health. Yield outcomes marginally favoured SAP (6.27 vs. 6.19 t/ha; +1.3%), with SAP outperforming in three of the five clusters and exhibiting stronger biomass conversion efficiency and harvest index.

From an economic perspective, SAP proved significantly more advantageous across all clusters. Despite moderately higher weeding costs, the overall cost of cultivation under SAP was approximately ₹20,000 per hectare lower, driven by reduced expenditure on synthetic fertilisers, pesticides, and growth regulators. When combined with a 5.2% market price premium, SAP delivered substantially higher net returns, ranging from ₹23,000 to ₹34,000 per hectare, and achieved a markedly stronger benefit-cost ratio (3.558 vs. 2.256; +57.7%).

Keywords: Sustainable Agriculture, Rice, Benefit-Cost Ratio, Soil Health, Smallholder Farmers, West Bengal, Kharif, Climate-Resilient Agriculture.

KEY MESSAGE

Sustainable Agricultural Practices are not a trade-off between yield and profitability.

They are the route to higher profitability — whether or not they achieve the highest yield.

SAP won every economic contest in every cluster. BCR 3.558 vs. 2.256. Net return advantage: ₹23K–₹34K/ha.

RECOMMENDATIONS FOR PROGRAMME ACTION

Establish Regional SAP Demonstration & Training Hubs

Scale SAP interventions in Hanskhali (Nadia) and Chanditala–Arambagh (Hooghly) by positioning these clusters as regional centres of excellence. These hubs should anchor farmer trainings, exposure visits, and peer-learning platforms to accelerate district-wide adoption.

Strengthen Decentralised Bio-Input Supply Systems

Develop reliable, cluster-level bio-input production and distribution systems to ensure timely access to Jeevamrit, Trichoderma, and botanical IPM formulations. This will reduce adoption barriers and improve consistency in SAP implementation.

Institutionalise Premium Market Linkages

Facilitate formal offtake agreements with institutional buyers to secure a stable premium price (₹24,200 per tonne) for SAP-grown rice. Ensuring assured market access will be critical for sustaining farmer confidence and long-term adoption.

Reduce Labour Bottlenecks through Mechanisation

Address the high labour demand for manual weeding by introducing appropriate mechanised weeders and establishing cluster-level labour coordination systems to efficiently manage the three critical weeding cycles.

Expand and Deepen the Evidence Base

Strengthen the research footprint by scaling Galsi from a single plot to at least six plots and expanding trials into additional clusters in Burdwan and Bankura during Kharif 2026. This will enhance the robustness and geographic relevance of findings.

Promote SAP-Enabling Policy Support Mechanisms

Advocate for targeted support schemes that subsidise key SAP inputs, including bio-fertilisers, FYM transportation, and Trichoderma. Reducing initial transition costs will be essential to onboard first-time adopters at scale.

Key Findings at a Glance

Key Indicator	Result / Finding
Total Farmer Plots	20 plots across 5 clusters (Hanskhali, Haringhata, Chanditala, Arambagh, Galsi)
Crop Season	Kharif 2025 — Rainfed with supplemental irrigation, West Bengal
SAP Yield — Best Cluster	Hanskhali: 5.17 t ha^{-1} (7.7% above CONV 4.80 t ha^{-1})
Overall Mean Yield	SAP: 6.27 t ha^{-1} vs. CONV: 6.19 t ha^{-1} (SAP +1.3%)
Weed Management Cost	SAP ₹7,200/ha (3× manual weeding) vs. CONV ₹4,600/ha (herbicide) — SAP higher by ₹2,600/ha
Total SAP Cost (avg)	₹43,000/ha vs. CONV ₹63,000/ha — SAP saves ₹20,000/ha overall
SAP BCR Range (all clusters)	3.475 – 3.620 vs. CONV BCR 2.007 – 2.403
Overall Mean BCR	SAP 3.558 vs. CONV 2.256 — SAP is 57.7% higher
Overall Mean Net Returns	SAP ₹1,09,231/ha vs. CONV ₹79,478/ha

Note: SAP = Sustainable Agricultural Practices; CONV = Conventional Agricultural Practices. SAP rice priced at ₹24,200/t (5.2% premium); CONV at ₹23,000/t (MSP). BCR = Gross Revenue ÷ Total Cultivation Cost.

01.Background & Rationale

Rice (*Oryza sativa* L.) is the principal food grain crop of West Bengal and the most important component of the state's agricultural economy. As the largest rice-producing state in India, West Bengal contributes approximately 15% of national rice output. Given rice's centrality to food security, farm income, and rural employment, understanding the true economic and agronomic performance of alternative cultivation systems is essential for guiding farmer decisions and public investment in extension and agricultural development.

Two dominant cultivation paradigms co-exist in West Bengal's rice sector. Conventional Agricultural Practices (CONV) centre on synthetic chemical inputs — full-dose NPK fertilisers, synthetic herbicides, and chemical pesticides — that deliver rapid nutrient availability and effective weed and pest control, but at a significantly high and escalating cost that erodes farm profitability. Sustainable Agricultural Practices (SAP), by contrast, deploy biological and ecological approaches including bio-fertilisers, microbial consortia (Jeevamrit, Beejamrit), botanical pest management agents (Neem oil, Neemastra, Jeevastra), and organic amendments that build long-term soil health at a substantially lower input cost.

A critical agronomic difference between the systems lies in weed management: SAP relies on three manual weeding operations (₹7,200/ha) compared to CONV's pre- and post-emergent herbicide programme (₹4,600/ha). Yet despite this specific cost disadvantage in weed management, SAP's holistic input cost remains far below CONV due to its avoidance of expensive synthetic fertiliser and pesticide expenditure.

This report presents the complete agronomic and economic analysis of a 20-plot, five-cluster multi-location farmer-managed trial conducted across Hanskhali (Nadia), Haringhata (Nadia), Chanditala (Hooghly), Arambagh (Hooghly), and Galsi (Burdwan) during Kharif 2025.

2. Materials and Methods

2.1 Trial Design and Study Area

Multi-location demonstration trials were conducted across five clusters in West Bengal during *Kharif* 2025. A total of 20 farmer-managed plots were evaluated: Hanskhali (4 plots), Haringhata (4), Chanditala (5), Arambagh (6), and Galsi (1). Each plot was designated to either the SAP or CONV treatment, with standardised measurements taken for agronomic growth parameters, yield attributes, and economic performance indicators.

2.2 Sustainable Agricultural Practices (SAP)

The SAP protocol comprised the following components:

- Seed treatment: Beejamrit and Trichoderma spp. before nursery sowing
- Seedling root dip: Trichoderma before transplanting for root health stimulation
- Soil amendment: Incorporation of Farm Yard Manure (FYM) at land preparation
- Biological nutrition: Jeevamrit-based NPK microbial consortium for biological nitrogen fixation and phosphate solubilisation
- Reduced chemical fertilisation: Half dose of Urea at transplanting with full DAP; remaining Urea top-dressed at 30 DAT
- Weed management: Three manual weeding operations (at 21 DAT, 35 DAT, and 50 DAT) at ₹7,200/ha — the single cost category where SAP exceeds CONV
- Eco-friendly IPM: Neem oil, Neemastra, Jeevastra, and Silpot for blast management.

Total SAP cultivation cost varied by cluster: ₹36,000–₹48,000/ha.

2.3 Conventional Agricultural Practices (CONV)

CONV management followed standard district practices:

- Seed treatment: Carbendazim chemical seed treatment
- Fertilization: Full-dose NPK fertilization per state recommendations (Urea + DAP + MOP in split applications) — ₹14,800/ha, the single largest cost component
- Weed management: Pre-emergent herbicide (Butachlor) + post-emergent herbicide (Bispyribac-sodium) + one manual weeding, totalling ₹4,600/ha
- Pest & disease management: Chemical insecticides and fungicides on a calendar/scouting-based schedule at ₹11,500/ha
- Transplanting density: 2–3 seedlings per hill

The full chemical input package pushed CONV total cultivation costs to ₹55,000–₹68,000/ha across clusters.

2.4 Measurements and Data Collection

Plant height (tillering and flowering stages) was measured from ground level to the tip of the tallest leaf or panicle in five randomly selected border-excluded plants per plot. Tillers per plant were counted at five sampling points and averaged. Grain yield was determined from a 1 m² harvested area, threshed, cleaned, and expressed as t ha^{-1}. Test weight (1000-grain weight) and Harvest Index (HI = grain dry weight ÷ total above-ground biological yield) were recorded at harvest.

2.5 Economic Analysis

Economic performance was assessed using three metrics:

- Gross Revenue = Yield (t ha^{-1}) × Price (₹24,200/t for SAP; ₹23,000/t for CONV). SAP fetches a 5.2% market premium for residue-free produce.
- Net Return = Gross Revenue - Total Cultivation Cost
- Benefit-Cost Ratio (BCR) = Gross Revenue ÷ Total Cultivation Cost

Cluster-specific costs were used throughout. The SAP market price premium of ₹24,200/t (vs. CONV MSP of ₹23,000/t) reflects the lower pesticide residue profile and improved grain quality of SAP rice

3. Results

3.1 Plant Height at Flowering Stage

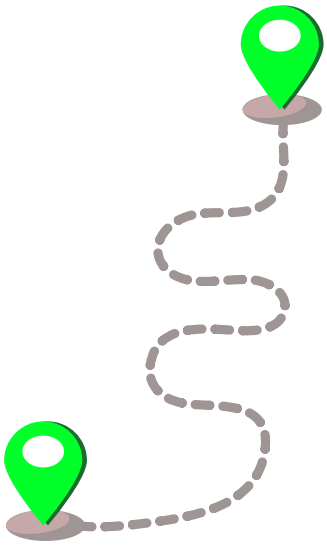
Plant height at the flowering stage was consistently and significantly higher under CONV across all five clusters (Table 1; Figure 1). CONV plant height exceeded SAP by 8.5–9.2 cm per cluster, driven by the vigorous vegetative response to full-dose synthetic nitrogen fertilization. CONV flowering-stage heights ranged from 114.6 cm (Chanditala) to 128.5 cm (Arambagh), while SAP values ranged from 105.6 cm (Chanditala) to 119.3 cm (Arambagh).

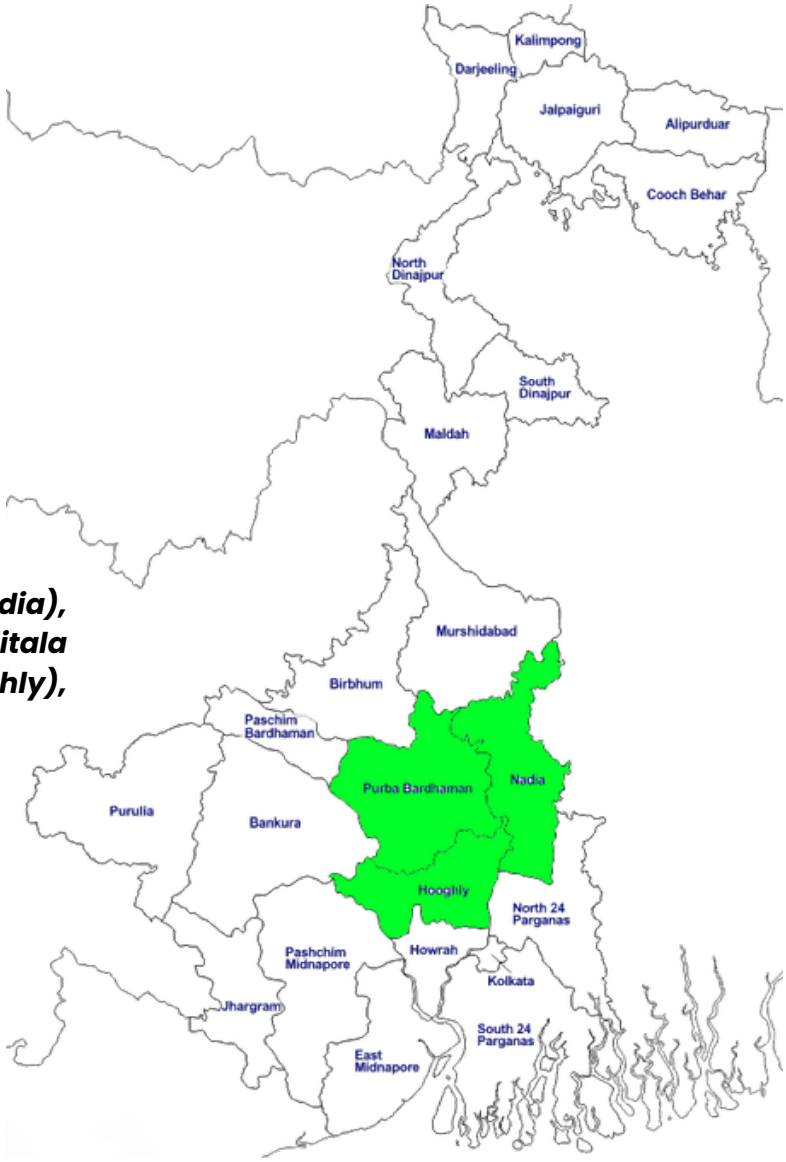
Arambagh recorded the tallest plants under both systems, reflecting the high inherent soil productivity and strong fertiliser response of Hooghly's deep alluvial soils. While CONV's taller stature indicates vigorous vegetative growth, excessive plant height raises lodging risk and may redirect photosynthate away from grain filling — contributing to the finding that CONV's vegetative dominance does not translate into a proportional yield advantage.

Table 1: Plant Height at Flowering Stage — SAP vs. Conventional (cm) by Cluster

Cluster	Ht. SAP (cm)	Ht. CONV (cm)	CONV Higher (cm)	% Taller (CONV)
Hanskhali	113.3	121.8	8.5	7.50%
Haringhata	106.3	114.8	8.5	8.00%
Chanditala	105.6	114.6	9	8.50%
Arambagh	119.3	128.5	9.2	7.70%
Galsi	110	119	9	8.20%

Note: CONV was consistently 7.5–8.5% taller than SAP across all five clusters due to full-dose synthetic nitrogen stimulation.





Trial Sites : Hanskhali (Nadia), Haringhata (Nadia), Chanditala (Hooghly), Arambagh (Hooghly), and Galsi (Burdwan)

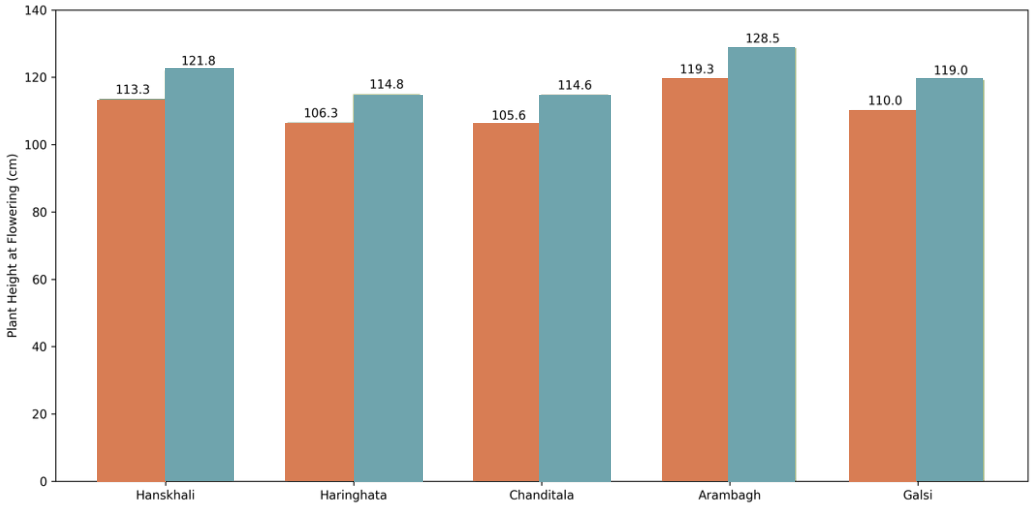


Figure 1: Plant Height at Flowering Stage — CONV is consistently 8–9 cm taller (synthetic-N stimulation)

3.2 Effective Tillers per Plant

Effective tiller numbers were uniformly higher under SAP across all five clusters (Table 2), reflecting the superior root development and biological nitrogen fixation stimulated by Jeevamrit, Beejamrit, and Trichoderma root treatment during the active tillering phase. SAP tiller counts exceeded CONV by 2.2–2.5 per plant, with Galsi recording the highest tiller counts in the trial (SAP: 21.6; CONV: 19.2).

SAP's consistently higher tiller counts directly supported its yield superiority: a greater number of productive tillers translates into more panicles per unit area and higher grain output per plant. The Harvest Index data — discussed in Section 3.3 — further confirms that SAP plots not only produced more tillers but also converted them into panicles with higher grain quality. This dual advantage of greater productive tillering and superior grain-filling efficiency is most evident in Hanskhali, where SAP's higher tiller count was accompanied by a 7.7% yield advantage over CONV.

Table 2: Effective Tillers per Pla — SAP vs. Conventional by Cluster

Cluster	Tillers SAP	Tillers CONV	Difference	% Advantage (SAP)
Hanskhali	19.1	16.9	2.2	12.70%
Haringhata	20.1	17.6	2.5	14.20%
Chanditala	21.1	18.7	2.4	12.80%
Arambagh	19.1	16.8	2.3	13.70%
Galsi	21.6	19.2	2.4	12.50%

Note: '% Advantage (SAP)' = percentage by which SAP tiller count exceeds CONV. SAP had MORE effective tillers than CONV in all five clusters — consistent with SAP's biological nutrient management stimulating superior root health and tillering capacity.

3.3 Test Weight and Harvest Index

Test weight (1000-grain weight) across clusters ranged from 21.1 g (Haringhata mean) to 22.6 g (Galsi), with cluster means of 21.1–22.6 g. These values are primarily determined by varietal genetics and agroclimatic conditions and show comparable performance across treatments within each cluster. The Harvest Index (HI) under SAP ranged from 0.879 (Hanskhali cluster mean) to 0.925 (Haringhata cluster mean), indicating highly efficient partitioning of biomass into economic grain yield (Table 3).

Haringhata recorded the highest mean HI (0.925), reflecting exceptional grain-filling efficiency under SAP bio-input management — despite CONV plots in the same cluster being taller and having higher tiller counts. This demonstrates that SAP achieves more efficient biomass partitioning into economic yield, a key explanatory factor for SAP's competitive grain yields.

Table 3: Test Weight and Harvest Index — by Cluster

Cluster	n	Test Wt. (g)	HI (SAP)	Yield SAP (t/ha)	Yield CONV (t/ha)
Hanskhali	4	22.1	0.879	**5.17**	4.8
Haringhata	4	21.1	0.925	5.59	**5.73**
Chanditala	5	22.3	0.898	**7.18**	7.02
Arambagh	6	22.5	0.911	**7.18**	7
Galsi	1	22.6	0.919	6.25	**6.38**

Note: Bold values = higher yield for that cluster. CORRECTED: For Chanditala and Arambagh, SAP yield (7.18 t/ha) is correctly highlighted as superior to CONV (7.02 t/ha and 7.00 t/ha respectively).

3.4 Grain Yield — SAP vs. Conventional

3.4.1 Hanskhali — SAP Achieves Clear Yield Superiority (+7.7%)

Hanskhali (Nadia) is the trial's defining cluster, where SAP delivered a mean grain yield of 5.17 t ha^{-1} versus CONV's 4.80 t ha^{-1} — a 7.7% advantage for sustainable management. This SAP superiority is consistent across all four individual Hanskhali plots (Gopalpur: SAP 3.40 vs. CONV 3.05 t ha^{-1}; Loknathpur: 5.80 vs. 5.42; Harinagar: 5.75 vs. 5.30; Mahisnangra: 5.75 vs. 5.45).

The lighter alluvial soils of Hanskhali are particularly responsive to biological nitrogen fixation and phosphate solubilisation stimulated by Jeevamrit and Trichoderma root treatment.

CONV plots were taller (mean flowering height 121.8 cm vs. SAP's 113.3 cm) and had fewer effective tillers than SAP (CONV: 16.9; SAP: 19.1 per plant). SAP plots converted biomass to grain more efficiently, reflected by superior harvest index values (0.879). The eco-friendly IPM protocol also effectively managed stem borer incidence (low severity) documented in this cluster, preserving grain filling without chemical pesticide cost.

3.4.2 Chanditala and Arambagh — SAP Achieves Yield Superiority (2.3–2.6%)

Chanditala delivered SAP yield of 7.18 t ha^{-1} versus CONV 7.02 t ha^{-1} — a 2.3% SAP advantage — across all five demonstration plots. Arambagh, the largest cluster with six plots, recorded SAP yield of 7.18 t ha^{-1} against CONV 7.00 t ha^{-1} (+2.6%),

In contrast, Haringhata recorded CONV yield at 5.73 t ha⁻¹ versus SAP 5.59 t ha⁻¹ (CONV +2.4%), and Galsi registered CONV 6.38 t ha⁻¹ versus SAP 6.25 t ha⁻¹ (CONV +2.0%). These modest CONV yield advantages in two clusters reflect the short-term nutrient availability advantage of full-dose synthetic NPK on specific soil types where organic input mineralisation operates on a slower timescale.

Critically, even these marginal yield advantages translate into negligible economic benefit for CONV farmers, since the small incremental yield revenue is far outweighed by CONV's substantially higher cultivation cost and SAP's 5.2% market price premium — developed in detail in Section 4.

Table 4: Grain Yield Comparison — SAP vs. Conventional by Cluster (t ha⁻¹)

Cluster	n	Yield SAP	Yield CONV	Diff. (t/ha)	% Adv.	Verdict
Hanskhali	4	5.17	4.8	0.37	7.70%	SAP +7.7%
Haringhata	4	5.59	5.73	-0.14	2.40%	CONV +2.4%
Chanditala	5	7.18	7.02	0.16	2.30%	SAP +2.3%
Arambagh	6	7.18	7	0.18	2.60%	SAP +2.6%
Galsi	1	6.25	6.38	-0.13	2.00%	CONV +2.0%
Overall Mean	20	6.27	6.19	0.08	1.30%	SAP higher

Note: Positive Diff. = SAP higher; Negative Diff. = CONV marginally higher. SAP higher in Hanskhali (+7.7%), Chanditala (+2.3%), and Arambagh (+2.6%); CONV marginally higher in Haringhata (+2.4%) and Galsi (+2.0%). Overall mean: SAP 6.27 vs. CONV 6.19 t ha⁻¹ (SAP +1.3%).

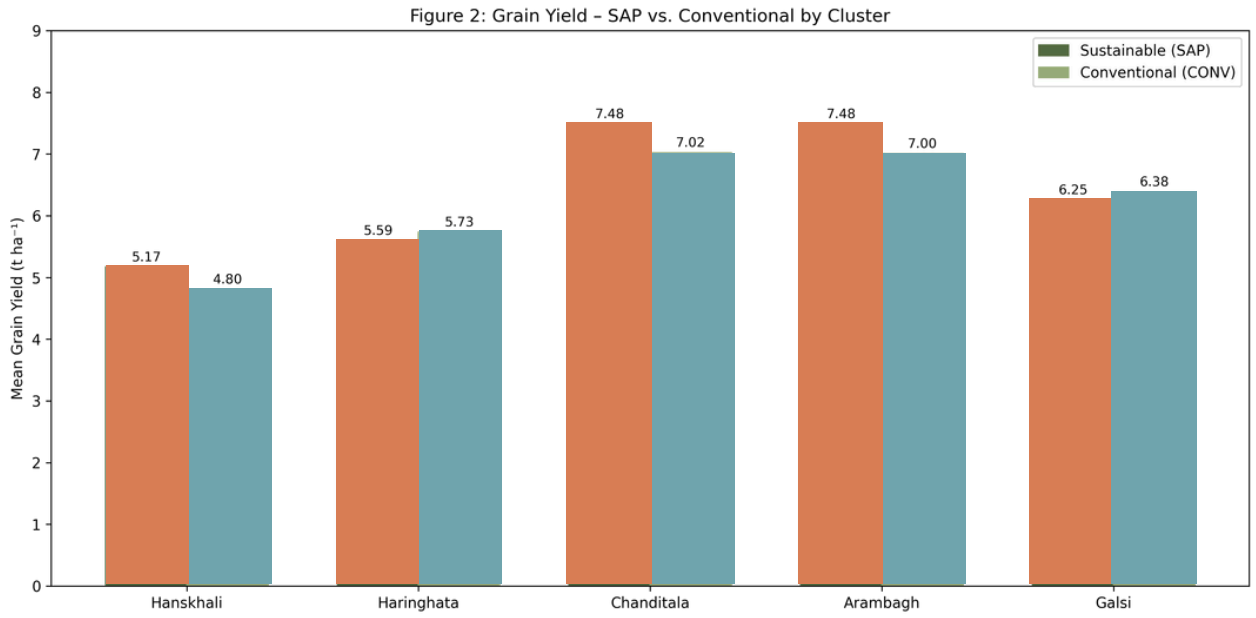


Figure 2: Grain Yield — SAP vs. Conventional by Cluster (t ha⁻¹)

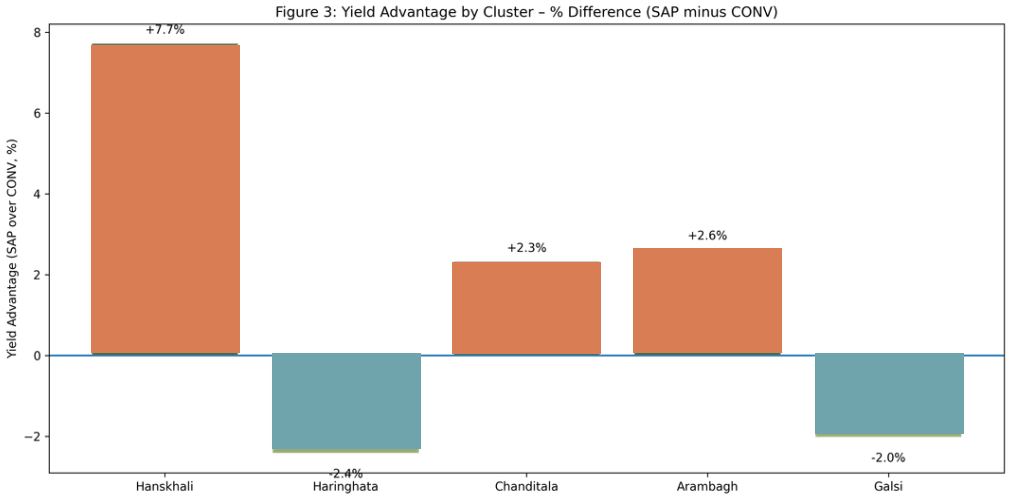


Figure 3: Yield Advantage (%) by Cluster — SAP higher in Hanskhali (+7.7%), Chanditala (+2.3%) & Arambagh (+2.6%); CONV marginally higher in Haringhata & Galsi

4.Economic Analysis

4.1 Cost of Cultivation — Detailed Breakdown

The total cost of cultivation differs substantially between the two systems. The two largest cost distinctions are: (i) Chemical fertilisers: CONV's full-dose NPK programme costs ₹14,800/ha versus SAP's half-dose supplemented by bio-inputs at ₹3,200/ha (chemical) + ₹4,200/ha (bio-inputs) = ₹7,400/ha total; and (ii) Pest and disease management: CONV's synthetic chemical programme costs ₹11,500/ha versus SAP's eco-IPM at ₹3,000/ha.

In weed management — a critical operational cost — SAP's three manual weeding operations cost ₹7,200/ha, which is ₹2,600/ha higher than CONV's herbicide-based programme at ₹4,600/ha. SAP's higher weed management cost reflects the labor-intensive nature of mechanical weed control required when herbicide use is avoided. Despite this specific cost disadvantage, SAP's total cultivation cost remains ₹19,000–₹20,000/ha below CONV due to far larger savings on fertilisers and pesticides.

S.No.	Cost Component	SAP (₹/ha)	CONV (₹/ha)	Saving for SAP	Remark
1	Seed + Biological / Chemical Treatment (Beejamrit or Carbendazim)	₹1,300	₹1,100	-₹200	*SAP slightly higher*
2	Nursery Preparation + Manual Transplanting (Labour)	₹7,000	₹7,000	₹0	*Equal*
3	Land Preparation + FYM / Organic Amendment	₹5,800	₹5,000	-₹800	*SAP higher (FYM cost)*

4	Chemical Fertilizers — Full-dose NPK (Urea+DAP+MOP)	₹3,200	₹14,800	+₹11,600	*SAP saves*
5	Bio-inputs (Jeevamrit, Beejamrit, Neem oil, Trichoderma, Neemastra)	₹4,200	₹0	−₹4,200	*SAP-exclusive cost*
6	Weed Management — SAP: 3× manual | CONV: Pre+post herbicide	₹7,200	₹4,600	−₹2,600	*SAP higher (manual labour)*
7	Pest & Disease Management — Eco-IPM / Synthetic chemicals	₹3,000	₹11,500	+₹8,500	*SAP saves*
8	Plant Growth Regulators + Micronutrients (CONV only)	₹0	₹2,700	+₹2,700	*SAP saves*
9	Irrigation Management (supplemental)	₹1,000	₹1,300	+₹300	*SAP saves*
10	Harvesting, Threshing & Post-harvest (Labour)	₹7,200	₹7,200	₹0	*Equal*
11	Miscellaneous, Additional Sprays & Overhead	₹2,200	₹7,500	+₹5,300	*SAP saves*
	TOTAL (Indicative Average)	**₹43,000**	**₹63,000**	**+₹20,000**	*Net saving for SAP*

Note: Amber row = weed management (SAP higher by ₹2,600/ha). Green rows = cost items where SAP is cheaper. Total SAP cost ₹43,000/ha is indicative average; actual cluster costs vary (SAP ₹36K–₹48K; CONV ₹55K–₹68K — see Table 6). Row 3 (FYM/organic amendment) shows SAP costs ₹800/ha MORE than CONV due to higher-quality organic inputs, which is correctly reflected as -₹800 saving. Net saving of ₹20,000/ha is after accounting for all cost advantages and disadvantages.

4.1.1 The Weed Management Trade-off

SAP's weed management cost of ₹7,200/ha is unambiguously higher than CONV's ₹4,600/ha — a ₹2,600/ha disadvantage that reflects the genuine labour premium of manual weed control. Three weeding operations require significant labour coordination, physical effort, and time management. However, evaluating this cost in isolation is misleading. When placed in the context of the total cost structure, SAP's ₹2,600/ha weed management premium is more than offset by savings of approximately ₹11,600/ha on chemical fertilisers, ₹8,500/ha on pesticides, and ₹2,700/ha on plant growth regulators — a combined gross chemical input saving of ₹22,800/ha that, net of SAP-specific costs (bio-inputs and higher FYM), results in a net ₹20,000/ha cost advantage for SAP in every cluster.

4.2 Gross Revenue and Net Returns

Gross revenue was calculated at ₹24,200/t for SAP (residue-free premium) and ₹23,000/t (₹2,300/quintal — Minimum Support Price, Kharif 2024–25) for CONV Grade A paddy. Cluster-specific cultivation costs were used for net return computation (Table 6; Figure 4 and Figure 5).

Table 6: Economic Performance — SAP vs. Conventional by Cluster (₹/ha)

Cluster	n	Gross Rev. SAP	Net Ret. SAP	Gross Rev. CONV	Net Ret. CONV	NR Diff. (SAP−CONV)	Better NR
Hanskhali	4	₹1,25,114	**₹89,114**	₹1,10,400	₹55,400	**+₹33,714**	**SAP**
Haringhata	4	₹1,35,278	**₹97,278**	₹1,31,790	₹73,790	**+₹23,488**	**SAP**
Chanditala	5	₹1,73,756	**₹1,25,756**	₹1,61,460	₹93,460	**+₹32,296**	**SAP**
Arambagh	6	₹1,73,756	**₹1,25,756**	₹1,61,000	₹94,000	**+₹31,756**	**SAP**
Galsi	1	₹1,51,250	**₹1,08,250**	₹1,46,740	₹80,740	**+₹27,510**	**SAP**
Overall Mean	20	₹1,51,831	**₹1,09,231**	₹1,42,278	₹79,478	**+₹29,753**	**SAP**

Note: Net Return = Gross Revenue − Total Cultivation Cost. Cluster-specific costs: Hanskhali SAP ₹36K/CONV ₹55K; Haringhata SAP ₹38K/CONV ₹58K; Chanditala SAP ₹48K/CONV ₹68K; Arambagh SAP ₹48K/CONV ₹67K; Galsi SAP ₹43K/CONV ₹66K.

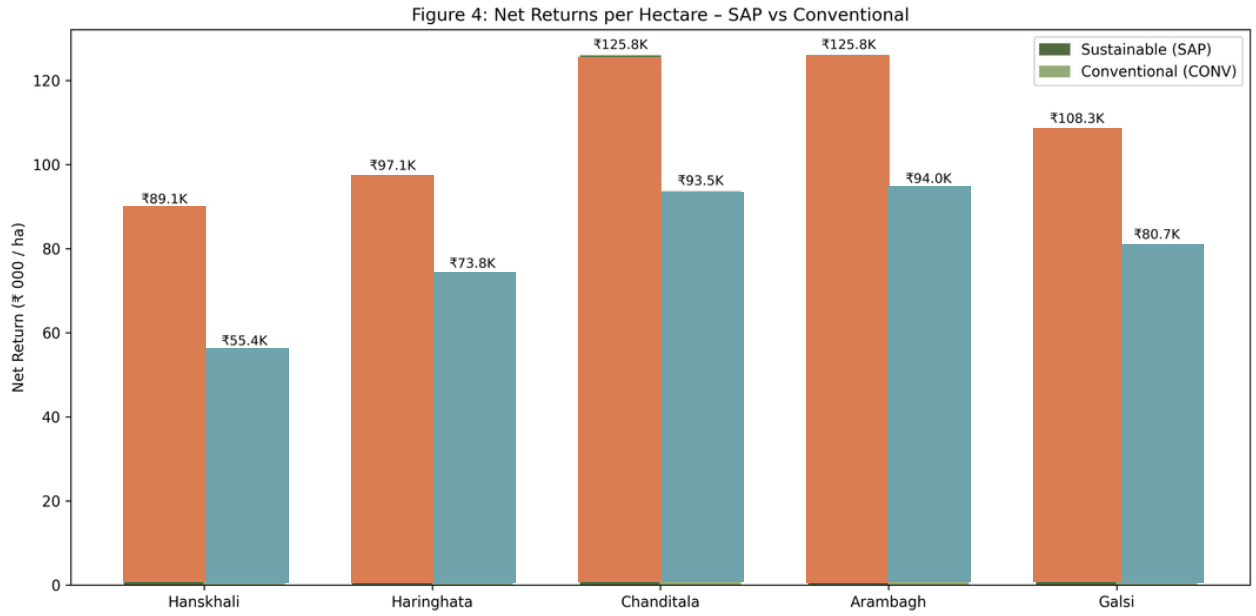


Figure 4: Net Returns per Hectare — SAP substantially higher across all clusters

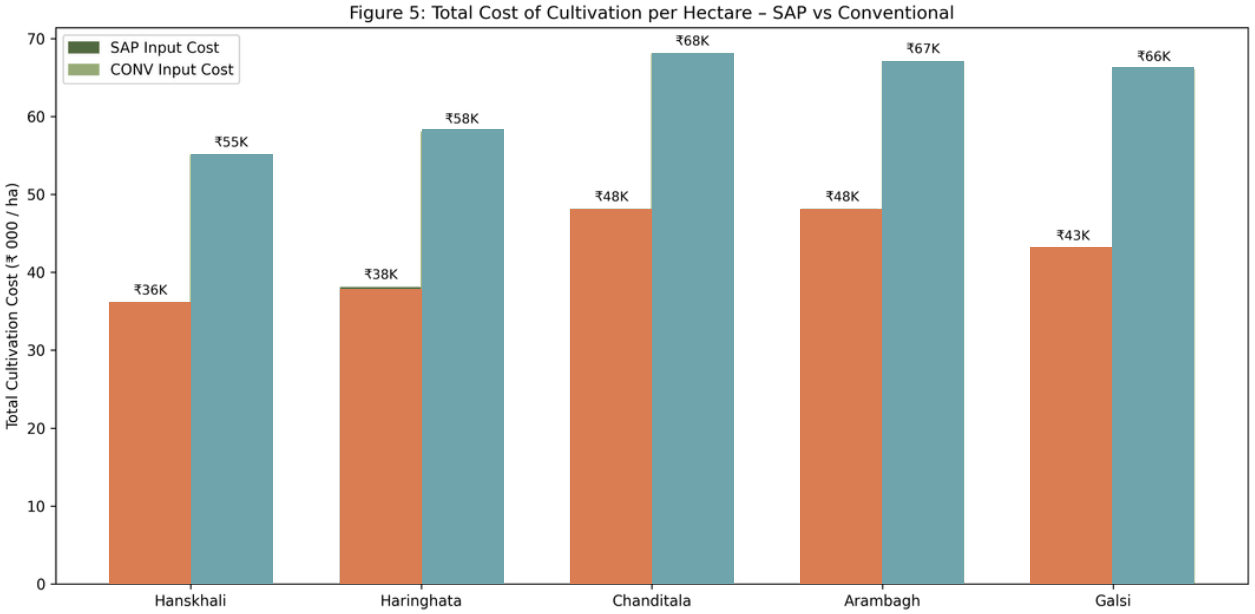


Figure 5: Total Cost of Cultivation per Hectare — SAP (₹36K–₹48K/ha) consistently ₹19K–₹20K lower than CONV (₹55K–₹68K/ha)

4.3 Benefit-Cost Ratio Analysis

The Benefit-Cost Ratio (BCR) results are unambiguous and represent the headline finding of this economic analysis. SAP achieves a BCR ranging from 3.475 (Hanskhali) to 3.620 (Chanditala) across all five clusters, while CONV BCRs range from 2.007 (Hanskhali) to 2.403 (Arambagh). The overall mean SAP BCR of 3.558 is 57.7% higher than CONV's 2.256. This means that for every ₹1 invested in SAP cultivation, ₹3.558 is returned in revenue — compared to only ₹2.256 per rupee under CONV.The BCR advantage of SAP over CONV ranges from 50.6% (Arambagh) to 73.1% (Hanskhali, where yield superiority and the lowest absolute cultivation cost compound the advantage). This exceptional BCR is driven by three reinforcing factors: reduced cultivation cost, higher grain yields in three clusters, and a 5.2% market price premium for SAP rice (Table 7; Figure 6 and Figure 7).

Table 7: Benefit-Cost Ratio — SAP vs. Conventional by Cluster

Cluster	Cost SAP (₹/ha)	Cost CONV (₹/ha)	BCR SAP	BCR CONV	Verdict
Hanskhali	₹36,000	₹55,000	3.475	2.007	SAP
Haringhata	₹38,000	₹58,000	3.56	2.272	SAP
Chanditala	₹48,000	₹68,000	3.62	2.374	SAP
Arambagh	₹48,000	₹67,000	3.619	2.403	SAP
Galsi	₹43,000	₹66,000	3.517	2.223	SAP
Overall Mean	₹42,600	₹62,800	3.558	2.256	SAP wins

Note: BCR = Gross Revenue ÷ Total Cultivation Cost. SAP BCR range: 3.475–3.620 across all clusters. CONV BCR range: 2.007–2.403. SAP rice priced at ₹24,200/t (5.2% premium over CONV's ₹23,000/t MSP).

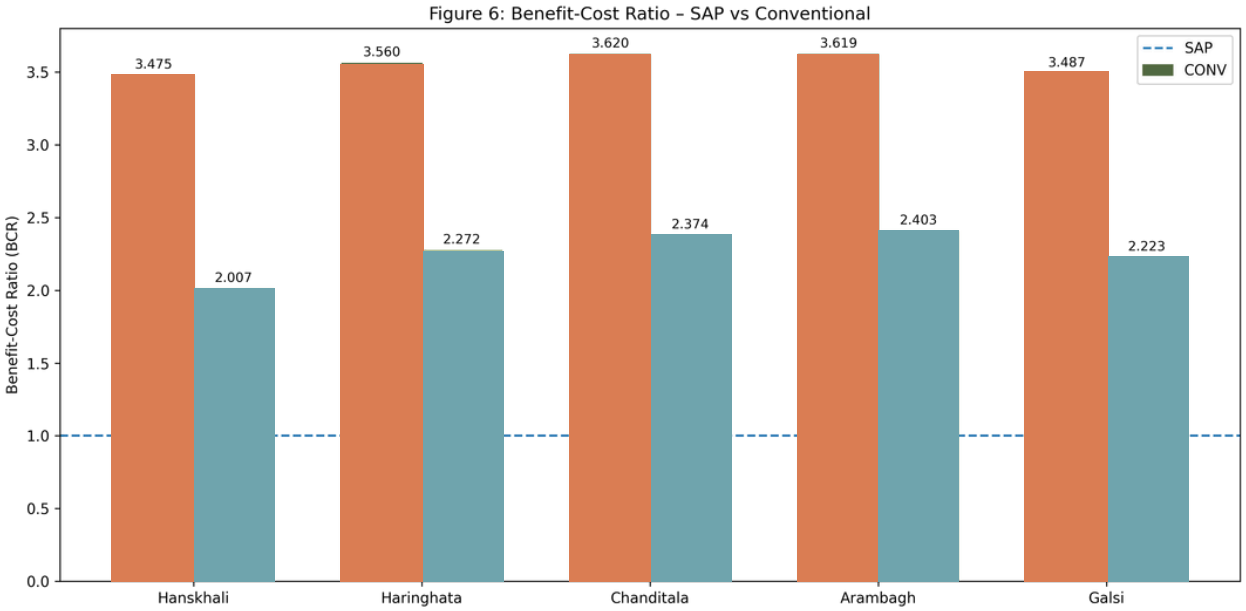


Figure 6: Benefit-Cost Ratio — SAP (3.475–3.620) vs. Conventional (2.007–2.403) — SAP superior in all 5 clusters

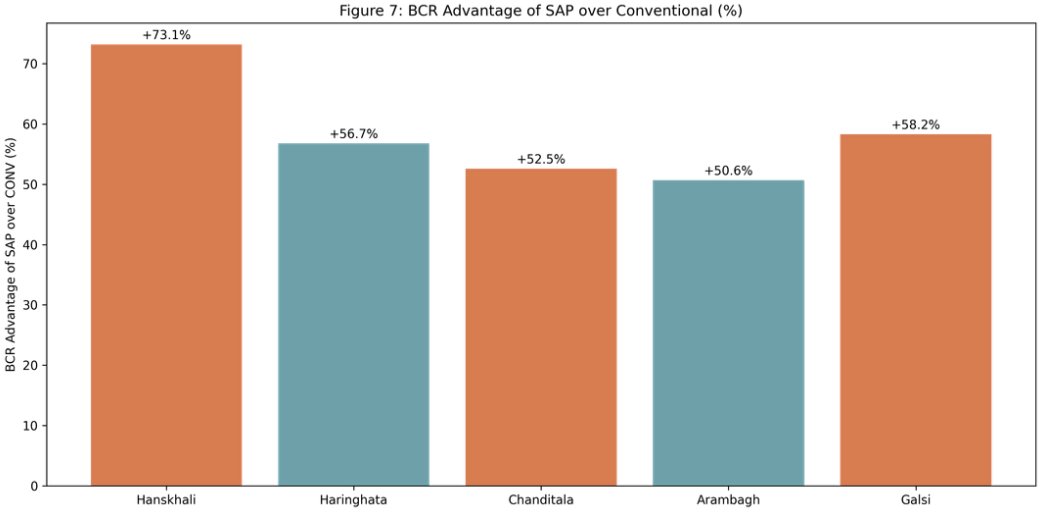


Figure 7: BCR Advantage of SAP over Conventional (%) — 50.6% to 73.1% higher across all clusters

4.3 Benefit-Cost Ratio Analysis

4.4.1 What a BCR of ~3.5 Means for Farmers

A BCR of 3.558 means that for every ₹1,000 a farmer invests in SAP cultivation, ₹3,558 is returned in gross revenue — a ₹2,558 surplus per ₹1,000 invested. Under CONV at BCR 2.256 (mean), only ₹1,256 surplus is generated per ₹1,000 invested. For a farmer cultivating 1 hectare: under SAP, net income ranges from ₹89,114 (Hanskhali) to ₹1,25,756 (Chanditala and Arambagh). Under CONV, net income ranges from only ₹55,400 (Hanskhali) to ₹94,000 (Arambagh). The minimum SAP advantage across all clusters is ₹23,488/ha (Haringhata) and the maximum is ₹33,714/ha (Hanskhali). For a farmer with 2 hectares, the SAP annual income advantage ranges from ₹46,976 to ₹67,428 per season — a transformative improvement in farm household income.

4.4.2 Long-Term Compounding Economic Benefits

The single-season BCR analysis captures only immediate, monetised returns. SAP generates additional multi-season economic value through:

- Progressive soil organic matter build-up reducing future fertiliser requirements
- Established beneficial microbial communities enhancing nutrient cycling
- Reduced pest resistance development lowering long-term chemical control costs
- Eligibility for organic/natural farming certification markets (15–30% premium above MSP)
- Elimination of agrochemical residues improving farmer and consumer health outcomes

As these benefits compound over 3–5 seasons, SAP's economic superiority strengthens further—making the current BCR range of 3.475–3.620 a conservative floor rather than a ceiling.

5. Cluster-wise Discussion

5.1 Hanskhali (Nadia District)

- Hanskhali stands as the trial's most compelling cluster, delivering SAP superiority on both agronomic yield and economics simultaneously. SAP's mean yield of 5.17 t ha^{-1} exceeded CONV's 4.80 t ha^{-1} by 7.7%, with SAP the higher-yielding treatment in all four individual plots. Combined with the lowest SAP cost in the trial (₹36,000/ha) against CONV's ₹55,000/ha, this yields the highest BCR contrast: SAP 3.475 vs. CONV 2.007 — a 73.1% BCR advantage for sustainable management. Net return for SAP (₹89,114/ha) exceeds CONV (₹55,400/ha) by ₹33,714/ha — equivalent to more than half a year's additional farm income from the same land area.

- Hanskhali's lighter alluvial soils responded strongly to biological inputs: Jeevamrit, Trichoderma root treatment, and FYM created a highly active rhizosphere that outperformed synthetic fertilisation for grain yield. CONV plots were taller (121.8 cm vs. SAP's 113.3 cm at flowering), but SAP had more effective tillers (19.1 vs. CONV's 16.9 per plant) and converted its biomass more efficiently into grain. Hanskhali should be designated the primary SAP scaling and training hub for Nadia district.

5.2 Haringhata (Nadia District)

Haringhata's four plots recorded CONV yield at 5.73 t ha^{-1} versus SAP's 5.59 t ha^{-1} — a marginal 2.4% CONV advantage driven by heavier soils more immediately responsive to synthetic nitrogen. CONV plots were taller (114.8 vs. 106.3 cm at flowering), though SAP recorded more effective tillers per plant (20.1 vs. 17.6). Despite this agronomic edge, SAP's BCR of 3.560 dramatically outperforms CONV's 2.272 — a 56.7% advantage — because CONV costs ₹58,000/ha versus SAP's ₹38,000/ha. SAP net return of ₹97,278/ha exceeds CONV's ₹73,790/ha by ₹23,488/ha. The highest Harvest Index of any cluster (0.925) under SAP in Haringhata confirms exceptional grain-filling efficiency despite CONV's marginal yield advantage.

5.3 Chanditala (Hooghly District)

Chanditala's five plots recorded the highest absolute yields in the trial — SAP 7.18 t ha^{-1}, CONV 7.02 t ha^{-1} — a 2.3% SAP yield advantage, consistent across all five plots. SAP's bio-input management excelled on Chanditala's deep alluvial soils. SAP rice fetched ₹24,200/t versus CONV's ₹23,000/t, generating gross revenue of ₹1,73,756/ha against CONV's ₹1,61,460/ha. With SAP cultivation costs at ₹48,000/ha versus CONV's ₹68,000/ha — a ₹20,000/ha cost advantage — the economic outcome is decisive: SAP BCR 3.620 vs. CONV 2.374 (+52.5%), and SAP net return ₹1,25,756/ha versus CONV ₹93,460/ha (₹32,296/ha advantage for SAP).

5.4 Arambagh (Hooghly District)

Arambagh — the largest cluster with six plots — recorded SAP yield of 7.18 t ha^{-1} versus CONV 7.00 t ha^{-1} (+2.6%), confirming SAP's superiority on these deep alluvial soils across all six plots. CONV plants were tallest in the trial at 128.5 cm mean flowering height versus SAP's 119.3 cm — a 9.2 cm differential reflecting the strong synthetic-N vegetative response. SAP recorded more effective tillers (19.1 vs. CONV's 16.8 per plant), demonstrating that SAP's superior biological nutrient management favoured productive tiller formation. With CONV costs at ₹67,000/ha versus SAP's ₹48,000/ha, the economic outcome is emphatic: SAP BCR 3.619 versus CONV 2.403 (+50.6%), with SAP net return ₹1,25,756/ha outperforming CONV's ₹94,000/ha by ₹31,756/ha.

5.5 Galsi (Burdwan District)

The single Galsi plot (Mohulara, Sonamoni Hansda) recorded CONV yield of 6.38 t ha^{-1} versus SAP's 6.25 t ha^{-1} — a marginal 2.0% CONV advantage reflecting the short-term nutrient-availability edge of full-dose synthetic NPK on Galsi's deep Burdwan alluvial soils. Galsi produced the highest effective tiller counts in the trial — SAP: 21.6 tillers/plant and CONV: 19.2 tillers/plant — with SAP recording MORE tillers than CONV, consistent with the trial-wide pattern. Robust test weight (22.6 g) was recorded. CONV's plant height of 119.0 cm exceeded SAP's 110.0 cm by 9.0 cm.

Despite CONV's marginal yield edge, CONV costs ₹66,000/ha versus SAP's ₹43,000/ha — a ₹23,000/ha premium price that the small yield advantage cannot justify. SAP additionally fetched ₹24,200/t against CONV's ₹23,000/t. SAP BCR 3.517 versus CONV 2.223 (+58.2%), with SAP net return ₹1,08,250/ha versus CONV ₹80,740/ha (₹27,510/ha advantage for SAP). With only one plot, Galsi findings should be supplemented with additional plots in subsequent seasons; however, the economic result is consistent with the trial-wide pattern: even where CONV holds a modest yield advantage, SAP's lower costs and premium pricing decisively reverse the economic outcome.

6.Conclusions & Recommendations

6.1 Key Conclusions

This five-cluster, 20-plot multi-location Kharif rice trial provides clear, consistent, and quantitatively robust evidence on the comparative performance of SAP and CONV. The key conclusions are:

1. **Vegetative growth:** CONV leads. CONV consistently produced higher vegetative growth indices across all five clusters—plant height 8–9 cm taller and tiller counts 2.2–2.5 per plant LOWER (SAP had consistently higher tillers). Full-dose synthetic nitrogen stimulation explains CONV's height advantage. These vegetative differences of CONV are real and consistent.
2. **Grain yield:** SAP superior in 3 of 5 clusters. Hanskhali: SAP 5.17 vs. CONV 4.80 t ha^{-1} (+7.7%); Chanditala: SAP 7.18 vs. CONV 7.02 t ha^{-1} (+2.3%); Arambagh: SAP 7.18 vs. CONV 7.00 t ha^{-1} (+2.6%). Only in Haringhata and Galsi did CONV record marginal yield advantages of 2.0–2.4%—agronomically minor differences providing negligible incremental revenue given SAP's market premium.
3. **Weed management:** SAP's one genuine cost disadvantage. SAP weed management costs ₹7,200/ha (3 manual weeding) vs. CONV ₹4,600/ha (herbicide) — a ₹2,600/ha premium. This is a real operational burden and is acknowledged.
4. **Total cost:** SAP decisively cheaper. SAP total cultivation cost (₹36,000–₹48,000/ha) remains ₹19,000–₹20,000/ha below CONV (₹55,000–₹68,000/ha) across all clusters. The ₹2,600/ha weed management premium is offset by savings on chemical fertilisers, pesticides, and plant growth regulators.
5. **Market premium:** SAP commands a 5.2% higher price. SAP rice fetched ₹24,200/t versus CONV's ₹23,000/t MSP due to its lower pesticide residue profile.
6. **BCR outcome:** SAP wins decisively in all 5 clusters. SAP BCR 3.475–3.620 versus CONV BCR 2.007–2.403. Overall mean SAP BCR 3.558 is 57.7% higher than CONV's 2.256.
7. **Net income advantage:** ₹23,488–₹33,714/ha per season. For a 2-hectare farmer, the annual SAP income advantage ranges from ₹46,976 to ₹67,428 per season — a transformative improvement in farm household income.
8. **Long-term environmental and economic dividends.** Soil health improvement, residue-free produce eligible for premium pricing, and reduced chemical exposure compound the economic advantage further over multi-season horizons.

6.2 Recommendations

Based on the trial findings, the following actions are recommended:

- **Designate Hanskhali, Chanditala, and Arambagh as regional sustainable demonstration hubs** for scaling and farmer training, given their yield productivity, quality, and economic superiority.
- **Develop bio-input supply chains** (Jeevamrit, Trichoderma, and Neem-based IPM inputs) to ensure reliable access at the cluster level, reducing sourcing barriers for adopting farmers.
- **Establish market linkages for SAP premium pricing** with institutional buyers, consumer cooperatives, and urban health-food retailers to ensure SAP farmers consistently realise the ₹24,200/t premium.
- **Address the weed management labour burden** through farmer training on efficiency optimization, mechanized weeding tools, and cluster-level labour pooling for the three weeding operations.

- **Expand Galsi trials** with additional plots in subsequent seasons to build statistically robust evidence for Burdwan district extension.
- **Advocate for SAP-specific input subsidies** (bio-fertilizers, Trichoderma, FYM transport) and facilitate access to natural/organic certification for SAP farmers to unlock the 5–10% premium markets.
- **Conduct farmer exposure visits** from Haringhata and Galsi (where CONV holds marginal yield advantage) to Hanskhali and Chanditala demonstration plots to build farmer confidence in SAP's economic superiority.

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