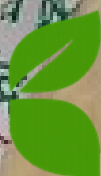


IMPACT REPORT 2021-2025

PROJECT BANDHAN: A KNOT OF PBW PROTECTION



SOUTH ASIA
BIOTECHNOLOGY
CENTRE



SCALING NOVEL MATING DISRUPTION TECHNOLOGY
ACROSS INDIA'S COTTON BELT
JULY 2026

EXECUTIVE SUMMARY

“Project Bandhan – A Knot of PBW Protection” represents one of India's largest field-scale adaptive demonstrations of pheromone-based mating disruption technology (PBKnot) for the sustainable management of Pink Bollworm (*Pectinophora gossypiella*) in cotton. Conceived as a science-driven, farmer-centric initiative, the project aimed to reduce dependence on chemical insecticides while restoring the effectiveness of integrated pest management (IPM) of devastating pink bollworm through an environmentally safe, area-wide pest management approach. Implemented across the Northern, Central and Southern cotton-growing zones, the project covered 3,102 acres in seven states and directly benefited 30,195 stakeholders, including cotton farmers, extension personnel and other value-chain actors. The initiative was supported by the PI Foundation, technically guided by the ICAR-Central Institute for Cotton Research (ICAR-CICR), and implemented by the South Asia Biotechnology Centre (SABC) in collaboration with an extensive network of State Agricultural Universities (SAUs), ICAR Regional Research Stations (RRSs), Krishi Vigyan Kendras (KVKs), State Departments of Agriculture, Farmer Producer Organisations (FPOs) and other local partners.

The project generated compelling evidence on the effectiveness of pheromone-based mating disruption as a sustainable alternative to conventional insecticide-intensive pink bollworm management. Compared with conventional farmer practices, PBKnot technology reduced male moth catches in pheromone traps by 83.14%, flower damage by 82.34% and green boll damage by 73.26%, demonstrating excellent suppression of pink bollworm populations and crop damage. The technology also reduced the cost of cotton cultivation by 14.7%, lowered insecticide applications by 28% & delivered an average seed cotton yield advantage of 1.75 quintals per acre, resulting in significant economic benefits for participating farmers.



Beyond technology validation, Project Bandhan established a comprehensive model for technology dissemination, farmer capacity building and multi-stakeholder collaboration. Through large-scale demonstration clusters, farmer field days, training programmes, technical workshops and continuous field monitoring, the project accelerated awareness and adoption of environmentally responsible pest management practices among cotton-growing communities. Project Bandhan demonstrates that area-wide pheromone-based mating disruption is not only technically effective but also economically viable, environmentally sustainable and scalable under Indian farming conditions. The initiative provides a strong scientific foundation for integrating mating disruption technology into India's national cotton pest management strategy and offers a practical pathway for reducing pesticide dependence, delaying insecticide resistance, improving farmer profitability and supporting the Government of India's vision for sustainable and climate-resilient cotton production.

Geographic Coverage & Distribution of Project Bandhan (2021-2025):

Project Bandhan was implemented between 2021 and 2025 as one of India's largest collaborative initiatives to demonstrate PBKnot pheromone-based mating disruption technology for sustainable management of pink bollworm in cotton. The initiative was implemented across the Northern, Central and Southern cotton-growing zones, covering 7 states, 23 districts and 53 demonstration clusters. Over five Kharif seasons, PBKnot technology was deployed across 3,102 acres, directly benefiting 30,195 stakeholders, including cotton farmers, extension personnel and rural communities. The project established a strong multi-stakeholder partnership involving State Agricultural Universities (SAUs), ICAR Regional Research Stations (RRSs), Krishi Vigyan Kendras (KVKs), State Departments of Agriculture, NGOs and other local organizations.

Table 1. Sector-wise Engagement, Implementing Partners and Technical Support under Project Bandhan (2021-2025)

Implementing Agency: South Asia Biotechnology Centre (SABC), Jodhpur			
Funding Agency: PI Foundation, Gurugram			
Technical Guidance: ICAR-Central Institute for Cotton Research, Nagpur			
Zone	State	District	Implementing partners
North Zone	Haryana	Sirsa	South Asia Biotechnology Centre, Jodhpur
		Fatehabad	
	Punjab	Mansa	Ambuja Cement Foundation, Mumbai
		Bathinda	
		Abohar	South Asia Biotechnology Centre, Jodhpur
		Fazilka	
	Rajasthan	Hanumangarh	Ambuja Cement Foundation, Mumbai
		Sriganganagar	South Asia Biotechnology Centre, Jodhpur
Central Zone	Maharashtra	Nagpur	Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola and Agrovision Foundation, Nagpur
		Wardha	Krishi Vigyan Kendra, Wardha
		Yavatmal	Krishi Vigyan Kendra, Yavatmal and Action for Food Production (AFPRO), Delhi
		Amravati	College of Agriculture Amravati
		Buldana	Krishi Vigyan Kendra, Buldana
		Jalna	Krishi Vigyan Kendra, Jalna
		Jalgaon	Jain Irrigation Systems Ltd, Jalgaon
	Gujarat	Amreli	Ambuja Cement Foundation, Mumbai
		Rajkot	Action for Food Production (AFPRO), Delhi

South Zone	Andhra Pradesh	Guntur	Acharya N.G. Ranga Agricultural University (ANGRAU), Regional Agricultural Research Station (RARS), Lam Guntur
		Kurnool	Acharya N.G. Ranga Agricultural University (ANGRAU), Regional Agricultural Research Station (RARS), Nandyal
		Prakasam	NGO EFFORT Organisation
		Krishna	South Asia Biotechnology Centre, Jodhpur
	Telangana	Jammikunta	Krishi Vigyan Kendra, Jammikunta
		Warangal	
		Hanamkonda	

Beginning with a pilot demonstration in Nagpur in 2021, Project Bandhan rapidly expanded into a nationwide programme, demonstrating the scalability of pheromone-based mating disruption under diverse agro-climatic conditions. The project combined large-scale field demonstrations with farmer training, technology dissemination and institutional collaboration, creating a robust platform for promoting environmentally sustainable pink bollworm management. Its extensive geographic reach and strong public–private partnership model have established Project Bandhan as a nationally significant initiative for accelerating the adoption of integrated pest management technologies and supporting sustainable cotton production in India.

Chart 1. Overall Geographical Coverage of Project Bandhan, 2021-2025

Metric	Achieved
States covered	7
Districts covered	23
Total Number of Demonstration (cluster)	53
Area Under PBKnot (acres)	3102
Total beneficiaries	30195



Table 2: Year wise distribution of mating disruption technology demonstration and area covered, 2021-2025

Metric	2021	2022	2023	2024	2025
States covered	1	7	4	6	6
Districts covered	1	16	10	13	6
Total Number of Demonstration (cluster)	5	19	10	13	6
Area Under PBKnot (acres)	300	1160	710	598	334
Total beneficiaries	1700	11600	5900	8040	2955

Project Bandhan Beneficiary Footprint (2021–2025)

Project Bandhan reached a diverse community of direct and indirect beneficiaries including men and women cotton farmers, landless agricultural labourers, extension personnel and other stakeholders through its large-scale implementation across seven cotton-growing states during the Kharif seasons from 2021 to 2025.

Table 3. Overall beneficiaries including direct, indirect, men and women farmers from 2021-2025

Metric	Achieved
Direct Beneficiaries	30195
Indirect Beneficiaries	97500
Total men engaged	23280
Total women engaged	6915

Table 4. Year wise distribution of beneficiaries of Project Bandhan, 2021-2025

Metric	2021	2022	2023	2024	2025	Total
Direct Beneficiaries	1700	11600	5900	8040	2955	30195
Indirect Beneficiaries	15000	35000	14000	26000	7500	97500
Total men engaged	1374	8455	5060	5920	2471	23280
Total women engaged	326	3145	840	2120	484	6915



Capacity Building and Technology Outreach (2021–2025):

Project Bandhan implemented an extensive capacity-building programme comprising farmer training programmes, farmer fairs (Kisan Melas), exposure visits, critical input distribution, field demonstrations, stakeholder meetings, exhibitions and media outreach. These activities created a lasting impact by promoting the adoption of pheromone-based monitoring and PBKnot mating disruption technology across cotton-growing communities in the Northern, Central and Southern cotton zones during the Kharif seasons from 2021 to 2025.

Table 5. Year wise distribution of beneficiaries of Project Bandhan, 2021-2025

Metric	Achieved
Training Programs/ farmer melas	206
Exposure visits	42
Critical input distributions (Pheromone Traps)	9650
Critical input distributions (Safety Kits)	2600
Field visits	2258
Exhibitions	20
News article	147

Table 6. Year-wise distribution of on-filed capacity building programs on innovative mating disruption technology for sustainable cotton pest management

Metric	2021	2022	2023	2024	2025	Total
Training Programs/ farmer melas	9	49	38	75	35	206
Exposure visits	4	5	11	14	8	42
Critical input distributions (Pheromone Traps)	300	5000	1200	1800	1350	9650
Critical input distributions (Safety Kits)	500	1000	400	400	300	2600
Field visits	150	466	567	725	350	2258
Exhibitions	1	4	2	8	5	20
News article	19	23	31	45	29	147



Implementation Model and Technical Interventions:

- **Approach:** Area-wide mating disruption using PBKnot (20 cm long rope-based sealed polyethylene dispenser containing gossypure) combined with ICAR-CICR recommended IPM package of practices, demonstration clusters and farmer-facing extension.
- **PBKnot density and placement:** 9,875 dispensers per 25 hectares (approximately 158-160 ropes/acre); border: 1 rope/m; interior: 1 rope per 5 sq. meter.
- **Timing:** Installing PBKnot at 40 to 45 days after sowing (crop age and uniformity required for demo selection).
- **Monitoring:** One pheromone trap per hectare (25 traps per cluster); 100 flowers sampled per hectare for flower damage; standard checks for green boll and open boll/locule damage; yields recorded after multiple pickings.

Figure 1. Technical Details of PBKnot Mating Disruption Technology

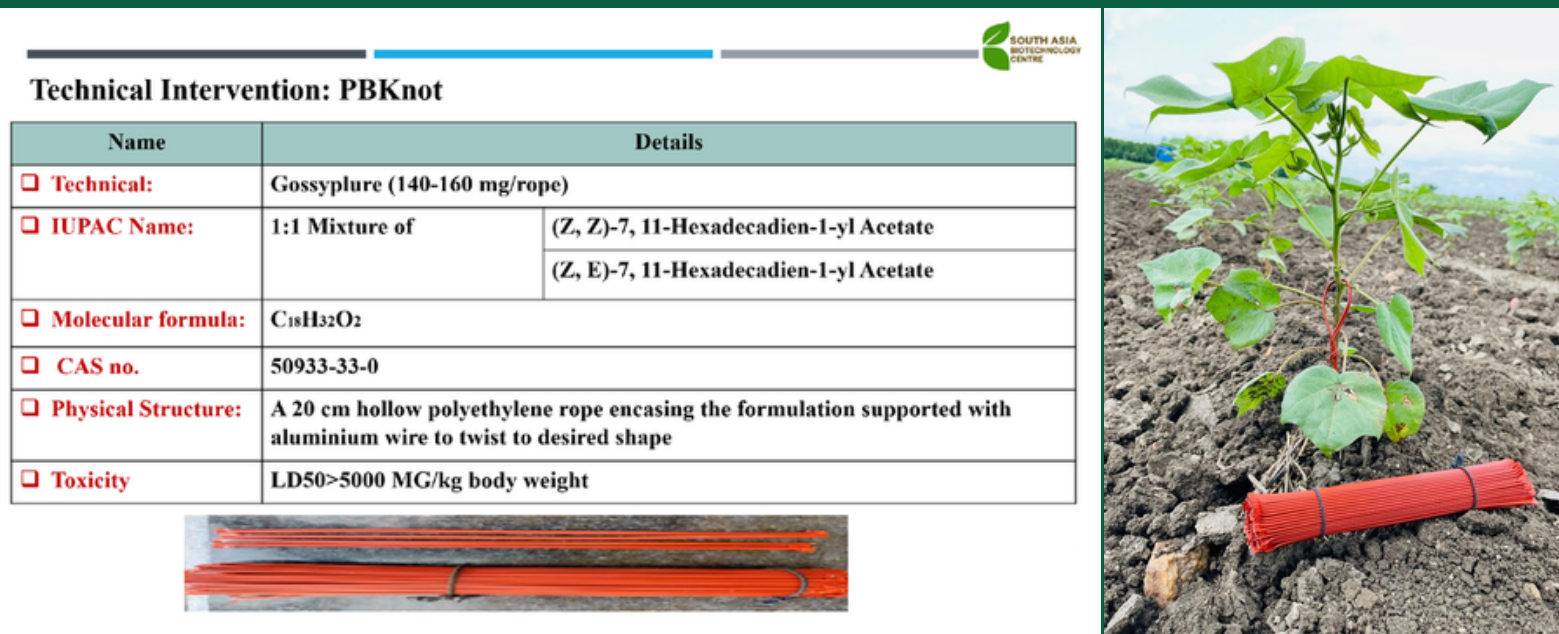
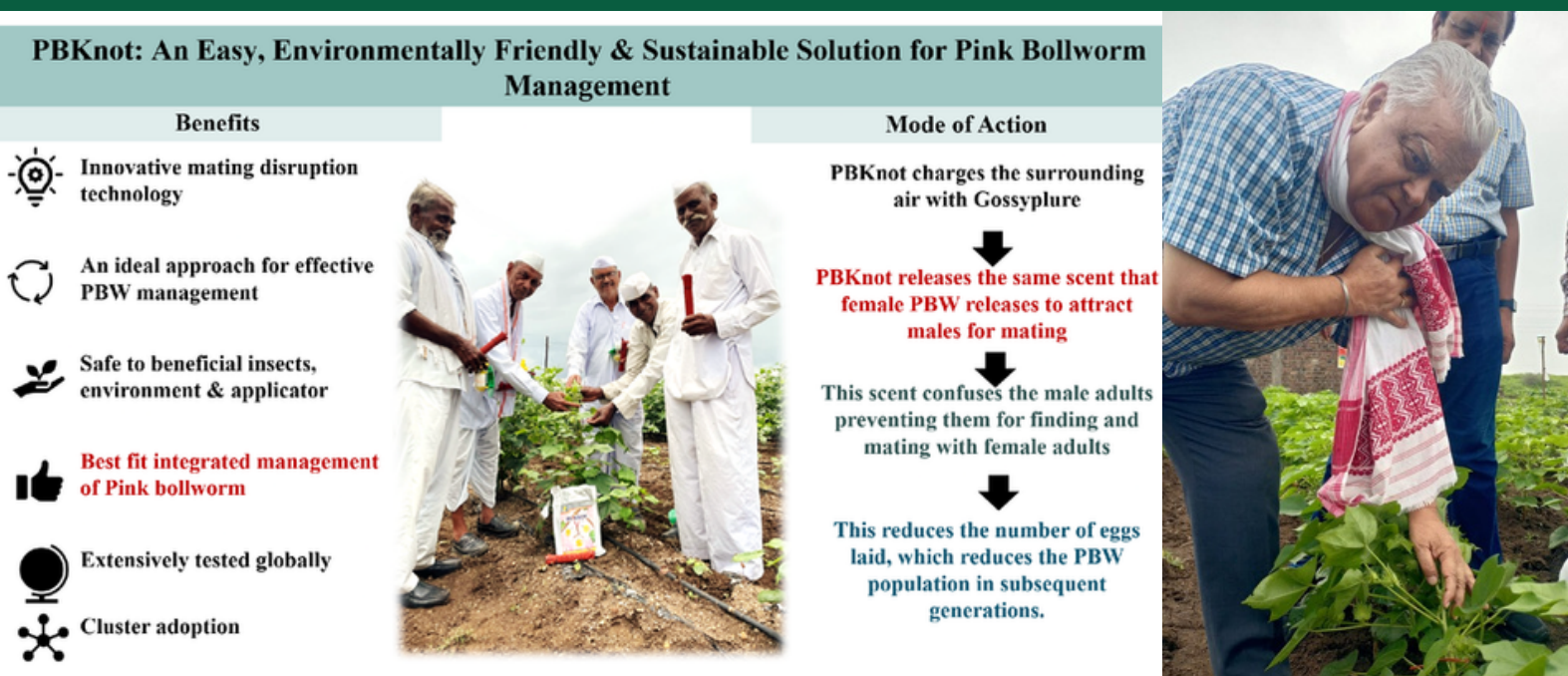


Figure 2. Overview of benefits and mode of action of PBKnot technology



Impact Summary: Transforming Pink Bollworm Management through Mating Disruption Technology

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Project Bandhan generated compelling scientific and field-level evidence demonstrating the effectiveness of PBKnot pheromone-based mating disruption technology for sustainable pink bollworm management in cotton. Across demonstration clusters, the technology achieved an 83.14% reduction in male moth catches, 82.34% reduction in flower damage and 73.26% reduction in green boll damage, indicating highly effective suppression of pink bollworm populations. The intervention also reduced insecticide applications by 28% and lowered the cost of cultivation by 14.7%, while increasing average seed cotton yield by 1.75 quintals per acre compared with conventional farmer practices. Beyond these measurable agronomic and economic benefits, Project Bandhan strengthened farmer knowledge through large-scale capacity building, promoted the adoption of environmentally safe pest management practices, reduced dependence on chemical insecticides, and established pheromone-based mating disruption as a scalable, farmer-friendly and climate-smart technology for sustainable cotton production across India's three major cotton-growing zones.

Table 7. Summary of Key Impact Indicators of Project Bandhan (2021-2025)

Year	Zone	Trap Catches Reduction (%)	Flower Damage Reduction (%)	Green Boll Damage Reduction (%)	Increase in Yield (Quintals/Acre)
Kharif 2021-22	North Zone	-	-	-	-
	Central Zone	90.70	51.20	42.00	1.50
	South Zone	-	-	-	-
Kharif 2022-23	North Zone	73.34	94.44	62.95	1.28
	Central Zone	46.78	83.33	45.30	1.72
	South Zone	80.50	49.85	82.79	1.78
Kharif 2023-24	North Zone	-	-	-	-
	Central Zone	89.85	86.61	78.02	1.31
	South Zone	90.44	82.50	66.41	1.63
Kharif 2024-25	North Zone	94.96	94.40	86.51	2.65
	Central Zone	86.32	77.55	91.95	1.70
	South Zone	95.78	89.45	79.08	1.58
Kharif 2025-26	North Zone	81.82	94.30	85.17	2.07
	Central Zone	86.76	89.01	76.81	1.24
	South Zone	80.40	95.44	82.10	2.53





Table 8. Comparative Average Performance of PBKnot Technology over Conventional Farmer Practices (2021-2025)

Indicator	Result
% Reduction in PBW trap catches vs control	83.14
% Reduction in flower damage vs control	82.34
% Reduction in green boll damage vs control	73.26
% Reduction in insecticide sprays vs control	27.97
% Reduction in cost of cultivation vs control	14.71
Increase in yield (quintals/acre) vs control	1.75

Year-wise Performance of PBKnot Mating Disruption Technology

Project Bandhan was implemented over five consecutive Kharif seasons (2021–2025) across the Northern, Central and Southern cotton-growing zones of India, representing one of the country's largest multi-location field evaluations of PBKnot pheromone-based mating disruption technology under diverse agro-ecological conditions. Despite seasonal variations in weather, pink bollworm pressure, cropping practices and production environments, the technology consistently demonstrated robust biological efficacy and delivered significant agronomic and economic benefits. Across locations and years, male moth catches in pheromone traps declined by 46.78–95.78%, reflecting effective disruption of the pink bollworm mating cycle and sustained suppression of pest populations. This translated into substantial reductions in crop damage and consistent seed cotton yield gains of 1.24–2.65 quintals per acre, confirming that pheromone-based mating disruption can reliably enhance productivity while reducing dependence on chemical insecticides.

Standardized Demonstration Protocol and Scientific Monitoring

A key strength of Project Bandhan was the adoption of a standardized cluster-based implementation and monitoring framework, ensuring scientific rigor, consistency and comparability of results across all demonstration sites. Each demonstration cluster comprised 25 hectares under PBKnot technology, accompanied by an adjacent 2-hectare untreated control, resulting in a 27-hectare monitoring unit for systematic evaluation. Every 25-hectare demonstration was installed with 9,875 PBKnot pheromone dispensers, following a uniform deployment protocol across all locations. Standard operating procedures were developed for pheromone trap monitoring, flower and green boll damage assessment, crop observations and yield estimation, enabling rigorous comparison of technology performance across regions and seasons. In addition, detailed records on pesticide use, cost of cultivation, farmer perceptions and economic returns were compiled through structured field observations, farmer interviews and field accounting. This harmonized monitoring framework generated a robust scientific evidence base demonstrating the technical efficacy, economic viability and scalability of pheromone-based mating disruption technology for sustainable pink bollworm management in India's cotton production systems.



Scientific Outreach, Extension and Information, Communication & Education (ICE):

Scientific outreach and farmer capacity building were central pillars of Project Bandhan, ensuring that pheromone-based monitoring and PBKnot mating disruption technology reached cotton-growing communities at scale. Between 2021 and 2025, the project conducted 206 farmer training programmes and Kisan Melas, 42 exposure visits, 2258 field visits and 20 agricultural exhibitions, complemented by the development of five technical knowledge products and dissemination through 147 news articles and publications. The outreach programme engaged a wide spectrum of stakeholders including cotton farmers, women farmers, Self-Help Groups (SHGs), Farmer Producer Organisations (FPOs), students, extension personnel and agricultural input dealers creating a strong knowledge ecosystem that significantly enhanced awareness, farmer confidence and the adoption of sustainable pheromone-based pink bollworm management across India's three major cotton-growing zones.

Farmer Testimonials and Case Highlights:

Farmer experiences across Haryana, Punjab, Rajasthan, Maharashtra, Gujarat, Andhra Pradesh and Telangana provided compelling evidence of the practical benefits of PBKnot pheromone-based mating disruption technology under diverse cotton production systems. Participating farmers consistently reported substantial reductions in pink bollworm infestation, fewer insecticide applications, healthier crops, improved boll retention, higher seed cotton yields and enhanced farm profitability. Several farmers indicated income gains of 15-20% owing to reduced crop losses and lower pest management costs. These real-world experiences closely corroborate the project's scientific findings, reinforcing that PBKnot technology is not only biologically effective and economically viable but also highly acceptable to farmers as a sustainable solution for pink bollworm management. Selected farmer testimonials presented in this report illustrate the technology's transformative impact on productivity, profitability and farmer confidence.

Operational Challenges and Adaptive Management:

While Project Bandhan successfully demonstrated the effectiveness of PBKnot pheromone-based mating disruption technology across diverse cotton-growing regions, its implementation also highlighted several production challenges beyond pink bollworm management;

- Abiotic stress at early crop stages (extreme heat) affecting establishment.
- High pressure from sucking pests requires complementary management.
- Excess rainfall and waterlogging in some seasons complicates operations.
- Late-season fungal and bacterial outbreaks (boll rot, root rot) affecting quality and yield



Risk Mitigation Strategies and Key Lessons Learned

While the technology consistently proved effective in suppressing pink bollworm, the project highlighted that its full potential can be realized only when integrated with sound agronomic practices, standardized implementation protocols and comprehensive crop management. The following lessons emerged from five years of multi-location field implementation:

- Carefully select demonstration clusters with uniform crop stands, well-drained fields and certified Bt cotton hybrids to ensure scientific validity, reliable performance comparisons and effective area-wide implementation.
- Integrate PBKnot within a holistic Integrated Pest Management (IPM) strategy, supported by regular surveillance of sucking pests (whitefly, jassids, thrips and aphids) and timely crop protection interventions to minimize yield losses from non-target pests.
- Standardize the timing of PBKnot deployment and field monitoring, with dispenser installation at 40-45 days after sowing, uniform pheromone trap monitoring, and harmonized protocols for assessing flower damage, green boll damage and yield across all locations.
- Adopt a robust and centralized monitoring framework, based on 25-hectare PBKnot demonstration clusters supported by adjacent 2-hectare untreated control plots, to ensure high-quality data generation, impact assessment and evidence-based decision-making.
- Strengthen weather-based disease surveillance and rapid advisory systems, particularly during periods of excessive rainfall, to enable timely management of late-season diseases such as boll rot and root rot that can compromise lint quality and yield.
- Promote continuous farmer engagement and capacity building through regular field visits, demonstrations and advisory services to enhance technology adoption, improve compliance with recommended practices and sustain long-term impact.

These lessons provide a practical roadmap for scaling pheromone-based mating disruption as a core component of climate-resilient, integrated cotton pest management, while improving the efficiency, consistency and sustainability of future cotton production programmes.



Recommendations and the Way Forward

Project Bandhan has demonstrated that PBKnot pheromone-based mating disruption technology is a technically effective, economically viable and environmentally sustainable solution for managing pink bollworm under Indian farming conditions. Building on the experience gained over five years of implementation, the following strategic recommendations are proposed to accelerate the adoption and scaling of this technology while strengthening integrated cotton pest management across the country:

- Scale up area-wide implementation of PBKnot technology by establishing larger, contiguous demonstration clusters across major cotton-growing landscapes. Expanding the treatment area will enhance mating disruption efficacy, reduce reinfestation from neighbouring fields and improve economies of scale by lowering the per-acre cost of pheromone dispensers.
- Integrate PBKnot into a comprehensive Integrated Pest Management (IPM) package, incorporating routine surveillance and timely management of sucking pests, boll rot and other emerging diseases to safeguard the full yield potential and ensure season-long crop protection.
- Develop farmer-friendly economic decision-support tools, including a simple cost-benefit calculator and a programme-level financial model, enabling farmers, extension agencies and policymakers to quantify net income gains, return on investment and the economic advantages of adopting PBKnot technology.
- Strengthen women-led extension and community participation by expanding the involvement of women farmers, Self-Help Groups (SHGs) and Farmer Producer Organisations (FPOs) in technology dissemination, recognizing their important contribution to cotton production and the significant socio-economic benefits observed among smallholder farming households.
- Institutionalize a standardized national monitoring and evaluation framework based on a core set of performance indicators including pheromone trap catches, flower and green boll damage, insecticide applications, cost of cultivation, yield and economic returns to facilitate consistent impact assessment and evidence-based policy decisions.
- Establish an open-access national database on PBKnot performance, enabling independent scientific validation, meta-analysis and continuous refinement of pheromone-based mating disruption strategies across different agro-climatic regions.
- Integrate PBKnot technology into national cotton development programmes, including the Mission on Cotton Productivity, to promote environmentally responsible pest management, reduce dependence on chemical insecticides, delay resistance development and support sustainable, climate-resilient cotton production.

Collectively, these recommendations provide a strategic roadmap for transforming PBKnot from a successful demonstration technology into a nationally scalable pest management solution capable of improving cotton productivity, enhancing farmer profitability and strengthening the long-term sustainability of India's cotton sector.

