Policy Paper

Biotic Stress Resilience in Agriculture: A Policy Framework

ICAR-National Institute of Biotic Stress Management, Raipur, Chhattisgarh
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Executive Summary

Indian agriculture faces mounting challenges from biotic stresses such as pests, pathogens, weeds, and microbial contaminants, which cause substantial yield losses, economic instability, and ecological degradation. Annual crop losses due to these biological factors are estimated at nearly ₹1.70–3.42 lakh crore annually, posing a serious threat to national food security and the livelihoods of millions of smallholder farmers. These pressures are further exacerbated by climate variability, monocropping systems, and excessive dependence on synthetic chemical inputs.

While India has made commendable progress in integrated pest management (IPM), biological control, and digital pest surveillance, its policy and regulatory frameworks remain anchored in an earlier, chemically intensive era. They do not adequately address the rapidly evolving realities of bio-inputs, gene editing, artificial intelligence–based pest forecasting, or drone-enabled precision applications. As a result, there exists a widening gap between scientific innovation and policy adaptation, limiting the scalability and sustainability of current pest management strategies.

This policy paper proposes an integrated and forward-looking framework for sustainable and scalable biotic stress management in Indian agriculture. It aligns scientific innovation, governance reforms, and community participation within the broader paradigms of One Health and biosecure farming. Drawing from extensive policy consultations, institutional assessments, and technical analyses, the framework presents a roadmap for modernizing pest and disease management systems through harmonized regulations, institutional convergence, and incentive-driven ecological stewardship.

The proposed framework emphasizes a shift from reactive pest control to preventive biosecurity management. It underscores the

modernization of agricultural governance through a unified legal structure, the creation of inter-agency coordination mechanisms, and the strengthening of biosecurity infrastructure and surveillance systems. It also advocates inclusive capacity-building programs targeting farmers, women, and youth, alongside financial and ecosystem-based incentives to promote sustainable practices and data-driven monitoring systems to ensure transparency and accountability.

Key Takeaways

- **Magnitude of Losses:** Biotic stresses lead to annual crop losses worth approximately ₹90,000 crore, undermining food and income security.
- **Policy Gaps:** Existing pest management laws and programs are fragmented and outdated, lacking provisions for modern biological and digital technologies.
- **Need for Unified Framework:** A comprehensive legal and institutional framework is essential to streamline pest and biosecurity governance across research, regulation, and implementation agencies.
- **Preventive and Incentive-Based Approach:** Transitioning from reactive pest control to preventive, ecosystem-based management supported by financial incentives can enhance resilience and sustainability.
- **Technological Integration:** Incorporating AI-driven surveillance, drone-based precision management, and gene-editing innovations into pest management will improve forecasting and reduce losses.
- **Regulatory Framework for Bio-Inputs:** A unified and risk-based regulatory framework is essential to harmonize the governance of biopesticides, biofertilizers, and biostimulants, ensuring quality

assurance, digital traceability, and farmer confidence in sustainable inputs.

- **Capacity Building:** Empowering farmers, women, and youth through participatory training and extension networks will strengthen the adoption of biosecure farming practices.
- **Alignment with Global Goals:** The framework supports India's national agenda for sustainable agricultural growth and aligns with UN Sustainable Development Goals (SDGs) on food security, responsible production, climate action, and ecosystem restoration.

Through these strategic measures, India can transition toward a resilient, eco-efficient, and inclusive pest management system that safeguards productivity, farmer welfare, and environmental integrity positioning the country as a global leader in sustainable biosecurity and agricultural transformation.

1. Introduction

1.1 Rationale

Biotic stresses including insect pests, pathogens, nematodes, and weeds remain among the most serious constraints on agricultural productivity in India. Globally, these stresses account for 20–40% yield losses annually (Oerke, 2006; FAO, 2022). In India, updated crop-wise assessments indicate that major food, feed, and commercial crops collectively experience 10–20% losses valued at ₹1.70–3.42 lakh crore per year, underscoring the urgency of addressing biotic stress management. Figure 1 provides an overview of the relative contribution of major biotic and abiotic factors to national crop yield losses, highlighting that insect pests and diseases account for the highest proportion of annual crop damage. This reinforces the central role of biotic pressures in shaping yield gaps and production instability across farming systems.

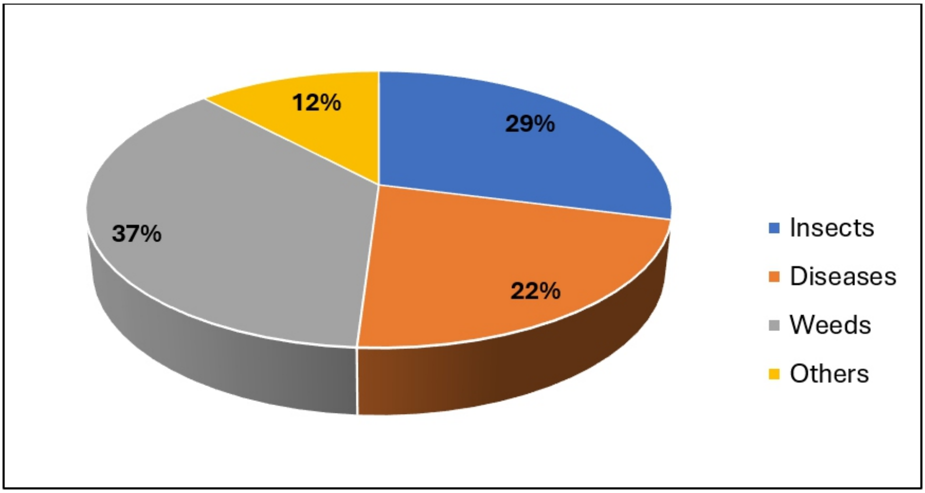

Figure 1: Proportion of annual crop yield loss in India attributed to different causes. Source: ICAR - DWR, 2024

These losses disproportionately affect the livelihoods of over 120 million small and marginal farmers, who form the backbone of

Indian agriculture. For these households, pest outbreaks can trigger cascading socio-economic hardships, including income instability, debt accumulation, reduced consumption, and heightened vulnerability to poverty. Figure 2 further illustrates the economic burden of biotic stresses by crop group, showing that cereals and horticultural crops incur the largest monetary losses. The visualization highlights how pest-related damage extends beyond field-level production to affect supply chains, market prices, food security, and national economic resilience.

Climate variability has intensified these challenges by reshaping pest biology, distribution, and virulence. Warmer winters, unpredictable rainfall patterns, and prolonged dry spells have expanded pest habitats and enabled the establishment of invasive species in previously non-endemic regions (Mahanta et al., 2023). At the same time, monoculture-based and high-input production systems have diminished ecosystem resilience by reducing populations of natural enemies and beneficial organisms. Excessive reliance on synthetic pesticides has further accelerated pest resistance, contributed to residue accumulation in food and soils, and disrupted natural biological control mechanisms (FAO, 2023). These ecological feedback loops have created an unsustainable dependence on chemical inputs, increasing production costs while posing risks to environmental and public health.

Addressing these interconnected challenges requires a comprehensive, science-driven policy response that integrates technological innovation, regulatory reform, and community-level implementation. Strengthened biosecurity systems, modern surveillance tools, eco-friendly crop protection strategies, and coordinated institutional mechanisms are essential to reduce losses, enhance resilience, and secure India's agricultural future.

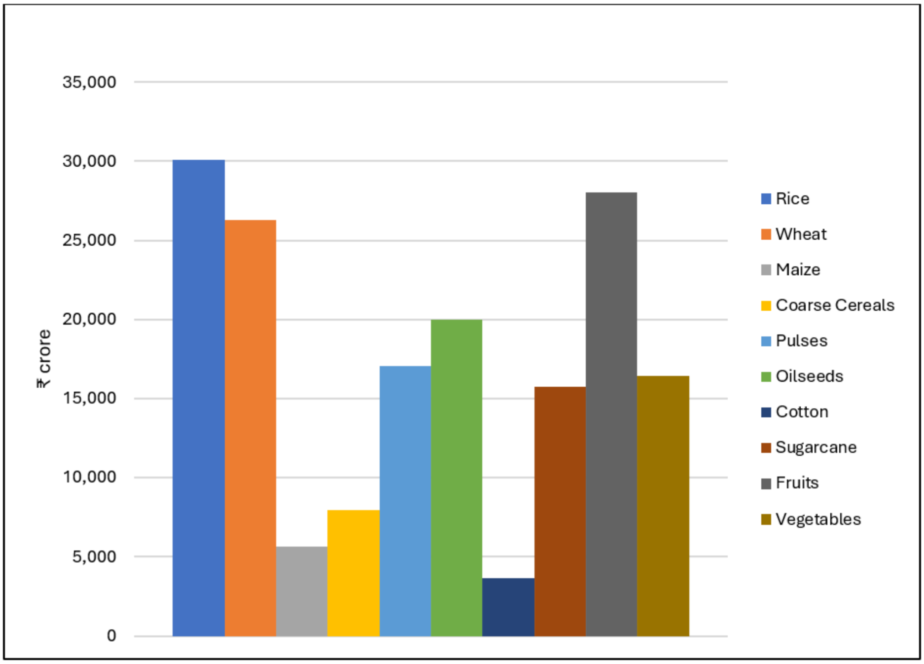

Figure 2: Distribution of estimated yield loss value due to insect pests and diseases among major crop groups in India under a 10% loss scenario

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1.2 Emerging Risks and Opportunities

With the liberalization of agricultural trade and the globalization of seed and planting material exchange, India's exposure to transboundary pest and disease incursions has increased significantly (Reddy et al., 2025b). The Plant Quarantine (Regulation of Import into India) Order of 2003 provides a legal foundation for phytosanitary controls; however, implementation gaps persist due to limited diagnostic infrastructure and a shortage of trained personnel (FAO, 2022). Outbreaks such as the Fall Armyworm (*Spodoptera frugiperda*) invasion since 2018 and the Black Thrips (*Thrips parvispinus*) epidemic that began in 2023 have demonstrated how quickly exotic pests can establish and spread in the absence of genomic surveillance and predictive modeling systems (Reddy et al., 2025a).

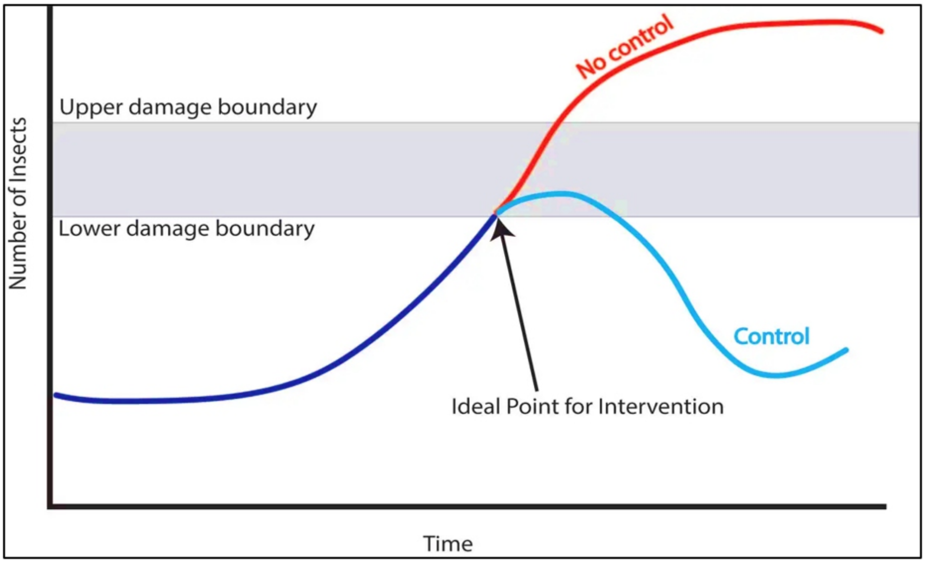

Figure 3: Insect population dynamics over time showing the ideal point for intervention

Despite these challenges, India is well-positioned to harness emerging scientific and technological advancements to transition toward preventive biosecurity management. Modern tools such as CRISPR-Cas gene editing, RNA interference (RNAi), metagenomics, AI-based pest forecasting, drone spraying, and remote sensing have opened new avenues for sustainable pest management (Ahale et al., 2024). Figure 3 depicts population fluctuations of pest species over time and identifies the threshold levels for timely intervention. It emphasizes the importance of predictive pest management, where control measures are applied before pest populations exceed economic thresholds, improving effectiveness while reducing chemical usage. These innovations, coupled with the growing bio-input industry, currently valued at approximately ₹1,200 crore and expanding by 15–18 percent annually, indicate the readiness of Indian agriculture for large-scale transformation (Shimpi et al., 2023).

Furthermore, increasing consumer demand for residue-free produce, the expansion of organic farming initiatives, and international commitments to the Sustainable Development Goals have created favorable policy and market conditions for mainstreaming eco-friendly pest management. Harnessing these opportunities requires coherent policies that integrate modern science with traditional ecological knowledge, fostering resilience, productivity, and environmental stewardship across the agricultural sector.

1.3 The Need for Policy Realignment

India's pest management policies have historically evolved around chemical-intensive agriculture. The Insecticides Act of 1968 and Insecticide Rules of 1971 were established during the Green Revolution to regulate the manufacture, sale, and use of chemical pesticides. While they served their purpose in ensuring productivity gains, these frameworks are now outdated and misaligned with contemporary pest management paradigms that emphasize biological control, digital innovation, and sustainability (MoA&FW, 2024). Likewise, biological inputs such as biopesticides, biofertilizers, and bio-stimulants are regulated under separate frameworks, including the Fertilizer Control Order (FCO) of 1985, leading to duplication, delays, and lack of harmonization (Reddy, 2025).

This fragmented governance architecture creates regulatory uncertainty and limits the scalability of eco-friendly innovations. The absence of unified standards and digital traceability mechanisms hampers the development of a transparent and accountable input market. As a result, substandard or counterfeit products proliferate, eroding farmer trust and disincentivizing genuine producers. Furthermore, limited public extension and over-reliance on private dealers have led to widespread misuse of chemical formulations, aggravating resistance development and environmental pollution.

From an institutional perspective, the responsibilities for research, regulation, and field implementation are distributed across multiple agencies such as the Indian Council of Agricultural Research (ICAR), State Agricultural Universities (SAUs), the Department of Agriculture & Farmers Welfare (DAC&FW), the Central Insecticides Board and Registration Committee (CIB&RC), the Department of Biotechnology (DBT), the Ministry of Environment, Forest and Climate Change (MoEFCC), and the National Bank for Agriculture and Rural Development (NABARD). The absence of a central coordinating authority has led to duplication of efforts and delays in the approval and dissemination of innovations (FAO, 2022). Additionally, gender and youth participation in pest management remain minimal, limiting social inclusiveness and community-driven adoption of sustainable practices (FAO, 2023). These gaps highlight the urgent need for an integrated and adaptive policy framework that bridges science, governance, and field-level implementation.

1.4 Policy Vision and Objectives

The integrated policy framework for sustainable biotic stress management envisions a paradigm shift from reactive, chemical-based control to proactive, ecologically balanced, and knowledge-driven pest management. It aims to align legislative, institutional, and financial mechanisms to support a holistic and sustainable approach that ensures food security, environmental protection, and farmer prosperity. The policy's vision is grounded in the One Health principle, recognizing the interconnectedness of plant, animal, human, and environmental health in maintaining biosecurity and resilience.

The core objectives of this framework are multifaceted. First, it seeks to modernize regulatory systems by developing a unified Bio-Input Regulation Act that harmonizes the governance of biopesticides, biofertilizers, and bio-stimulants under a single, risk-based and time-bound framework. Second, it aims to strengthen institutional convergence by establishing a National Council for Biotic Stress Management (NCBSM) to coordinate research, regulation, and field implementation. Third, it emphasizes biosecurity preparedness through enhanced surveillance, genomic diagnostics, and the integration of pest management with antimicrobial resistance monitoring. Fourth, it underscores the importance of extension and capacity building, particularly through Farmer Field Schools (FFS), Krishi Vigyan Kendras (KVKs), and community-based para-extension cadres, with a focus on empowering women and youth. Finally, it seeks to embed financial and ecosystem-based incentives, such as Ecosystem Service Payments (ESPs) and NABARD's Green Line of Credit (GLC), to reward farmers for adopting sustainable and bio-based practices.

Through these strategic objectives, the policy framework redefines pest management as both an agricultural and a national security imperative. It aligns India's agricultural governance with international sustainability commitments, enabling the country to achieve the dual goals of ecological balance and economic resilience while contributing to global food and environmental security.

2. Data and Methodology

2.1 Conceptual Framework

This integrated policy framework adopts a multidisciplinary, evidence-based approach combining scientific, institutional, and socio-economic perspectives on biotic stress management. It integrates principles of One Health, biosecurity, and sustainable intensification to balance productivity, ecology, and food safety. Recognizing that pest and pathogen pressures are shaped by climate variability, input use, and trade globalization (FAO, 2022), the framework moves beyond fragmented and reactive pest control mechanisms (MoA&FW, 2024). A systems-based perspective aligns digital surveillance, biological control, and genomic diagnostics with enabling policies, finance, and community participation ensuring interventions are both evidence-based and institutionally feasible.

2.2 Data Sources and Evidence Base

The framework draws on secondary data, institutional reports, and expert consultations. Core references include ICAR, NCIPM, CIB&RC, and MoA&FW databases, complemented by inputs from FAO, OECD, and FICCI. Quantitative data on crop losses, pesticide consumption, and bio-input adoption were compiled from national statistics and research publications. Comparative insights were drawn from OECD (2023) and FAO (2022) benchmarks. Multi-stakeholder dialogues including national workshops on Biotic and Abiotic Stress Management and consultations with ICAR, NABARD, and SAUs provided experiential inputs. This integration of empirical evidence and practitioner perspectives ensured scientific rigor with practical feasibility.

2.3 Methodological Approach

The framework employed a three-tiered approach: literature synthesis, institutional analysis, and policy benchmarking.

First, an extensive literature review identified the scale and trends of biotic stress in Indian agriculture, examining peer-reviewed studies and official reports on pest impact, pesticide resistance, and bio-input adoption (Sharma, 2006; FAO, 2022).

Second, an institutional review assessed the efficiency and gaps in regulatory mechanisms under the Insecticides Act (1968), Fertilizer Control Order (1985), and Plant Quarantine Order (2003), comparing them with international models from Japan, the U.S., and the EU (OECD, 2023).

Third, policy benchmarking aligned India's objectives with SDGs 2, 12, 13, and 15, ensuring coherence with global sustainability and governance standards.

2.4 Stakeholder Consultations and Participatory Inputs

Extensive consultations with scientists, policymakers, financial institutions, and farmer representatives shaped the framework. The 2025 National Workshop on Biotic and Abiotic Stress Management and follow-up sessions by ICAR–NCIPM and NAARM facilitated multi-agency coordination involving DBT, MoEFCC, NABARD, and State Agriculture Departments.

Feedback focused on unified bio-input regulation, pest surveillance strengthening, digital innovations, and incentives for IPM adoption. Inputs from FPOs, KVKs, FFS, and women farmer groups ensured inclusivity and on-ground relevance. The participatory process enhanced ownership and operational clarity for policy execution.

2.5 Analytical Framework for Policy Integration

The analytical synthesis connected science, policy, and practice through six thematic pillars: regulatory modernization, institutional convergence, biosecurity, capacity building, financial incentives, and accountability. Each was evaluated for policy relevance, feasibility, and sustainability alignment.

Gap and policy mapping analyses identified inconsistencies and proposed coherent, systems-based reforms. The framework thus provides an actionable, evidence-driven foundation for transforming India's pest management into a biosecure, innovation-led, and ecologically sustainable system.

3. Results and Discussion

3.1 Current Scenario of Biotic Stresses in Indian Agriculture

India's vast agroecological diversity supports more than fifty major crops, yet it also sustains an enormous range of pests, pathogens, and weeds that continually threaten productivity and profitability. Estimates indicate that pest- and disease-induced yield losses in Indian agriculture range between 10 and 20 percent annually, resulting in an economic impact of nearly ₹1.70–3.42 lakh crore annually (CropLife India, 2023). These losses directly affect national food security and indirectly raise the cost of cultivation through recurring pesticide expenditures. The combination of monocropping, high input intensity, and changing climatic patterns has created a favorable environment for pest proliferation while weakening natural control systems (FAO, 2022).

Climatic variability has played a crucial role in altering pest phenology and virulence. Warmer winters and increased humidity promote continuous breeding cycles for many insect species, while shifting rainfall patterns influence the distribution of fungal and bacterial pathogens. For example, the spread of *Spodoptera litura* and *Helicoverpa armigera* across multiple cropping systems has been linked to elevated temperatures and moisture fluctuations (Srinivasa Rao et al., 2022). Additionally, irrigation expansion and high-density planting have extended host availability, sustaining year-round pest activity. This complex interplay of climatic and agronomic drivers has redefined pest ecology in India's major production systems.

Table 1. India-Specific Estimated Crop Losses Due to Major Biotic Stresses

Crop Group	Estimated Loss (%) in India	Major Pests/Diseases	Reference
Rice	20–35%	Stem borer, brown planthopper, blast, BLB	ICAR-IARI (2023)
Wheat	10–20%	Rusts, aphids, foliar blights	ICAR-IIWBR (2023)
Maize	20–30%	Fall armyworm, leaf blights	AICRP–Maize (2022)
Coarse Cereals (Jowar, Bajra, Ragi)	15–25%	Shoot fly, stem borer, downy mildew	AICRP–Millets (2023)
Pulses	25–35%	Pod borer, wilt, sterility mosaic	ICAR-IIPR (2023)
Oilseeds	25–35%	Groundnut rosette, stem fly, white rust; soybean pests	AICRP–Oilseeds (2023)
Cotton	20–30%	Pink bollworm, whitefly	ICAR-CICR (2022)
Sugarcane	8–15%	Shoot borer, top borer, red rot	ICAR-SBI (2022)
Fruits	20–35%	Fruit fly, mealybugs, hopper, fungal rots	NHB (2023)
Vegetables	30–50%	Brinjal SFB, thrips, late blight in potato/tomato	ICAR-IIVR (2023)

The estimated crop loss ranges presented in Table 1 illustrate the significant variability and severity of biotic stress impacts across major Indian crop groups. Vegetables and pulses experience the highest proportional losses, often exceeding 30–50%, due to their susceptibility to insect borers, viral diseases, and fungal pathogens, coupled with inadequate pest surveillance and rapid pathogen spread. Fruits and rice also show substantial losses, largely driven by fruit flies, fungal rots, stem borers, and blast disease, reflecting the high pest pressure in humid and subtropical ecosystems. Oilseeds and cotton continue to face recurring challenges from emerging and re-emerging pests such as stem fly, white rust, and pink bollworm, while wheat and sugarcane experience relatively lower yet economically significant losses due to rusts, borers, and red rot. This crop-wise loss distribution underscores the urgent need for differentiated, crop-specific integrated pest management strategies and highlights how biotic stresses remain a central driver of yield gaps, production instability, and increased dependency on chemical pesticides in Indian agriculture.

Estimated Production, Crop Losses, and Economic Value of Major Crop Groups in India

India's major crop groups exhibit substantial vulnerability to biotic stresses, resulting in significant physical and monetary losses across the agricultural value chain. Using recent production figures and farm-harvest price data for 2023–24, the estimated economic losses under 10% and 20% loss scenarios highlight the magnitude of risks caused by insect pests and diseases. Table 2 presents updated calculations for cereals, pulses, oilseeds, horticultural crops, and commercial crops, illustrating both physical losses (in million tonnes) and their corresponding economic implications (₹ crore). These estimates underscore the urgent need to strengthen pest surveillance systems, invest in scientific storage and supply-chain infrastructure, and promote climate-resilient, biosecure agricultural practices.

Cereal Crops (Rice, Wheat, and Coarse Cereals):

Cereal crops form the backbone of India's food security system and therefore experience high economic exposure to pest-induced yield losses. Rice production stands at 137.83 million tonnes, and even a 10% loss (13.78 Mt) results in a direct economic impact of ₹30,066 crore, doubling to ₹60,132 crore under a 20% loss. Wheat shows similarly high sensitivity with 113.29 Mt production, where losses range from ₹26,307 crore to ₹52,614 crore. Maize and other coarse cereals collectively contribute more than 94 million tonnes, and their loss values under 10–20% stress scenarios range between ₹5,650 crore and ₹15,942 crore.

These losses are largely driven by insect pests, storage pests, rodent damage, drying inefficiencies, and inadequate storage infrastructure, especially in decentralized procurement locations.

Pulses and Oilseeds:

Pulses and oilseeds, essential for national protein and edible oil security, face some of the highest per-tonne monetary losses due to their higher market value. With production of 24.25 Mt, pulses incur losses worth ₹17,084 crore to ₹34,169 crore across 10–20% scenarios. Oilseeds, at 39.67 Mt, show even higher losses ranging from ₹19,999 crore to ₹39,998 crore largely due to susceptibility to fungal infestation, insect damage, and post-harvest moisture issues. Strengthening scientific storage, processing, and decentralized oilseed-crushing units would greatly reduce these losses.

Horticultural Crops (Fruits and Vegetables):

Horticultural crops are highly perishable and therefore particularly vulnerable to rapid physical deterioration when exposed to pest damage. India produces 112.08 Mt of fruits and 205.80 Mt of vegetables, with 10% losses valued at ₹28,020 crore and ₹16,464 crore, respectively. These figures double under 20% loss scenarios, emphasizing the need for cold chain investment, pack-house facilities, and improved market logistics to minimize waste.

Commercial Crops (Cotton and Sugarcane): Cotton and sugarcane exhibit non-trivial economic losses under biotic stress conditions. Cotton (equivalent to 5.53 Mt) experiences losses valued at ₹3,659 crore to ₹7,318 crore, while sugarcane (at 453.16 Mt) faces losses worth ₹15,728 crore to

₹31,456 crore. These losses stem from pre-harvest pest attacks, moisture loss, delayed processing, and deterioration during transport to crushing points.

Overall Scenario and Implications:

Across all crop groups, cumulative losses at 10% and 20% biotic stress levels amount to 118.62 Mt and 237.24 Mt, respectively representing an economic value of ₹1,70,948 crore and ₹3,41,897 crore. These figures illustrate the national-scale implications of pest-induced damage and reinforce the need for integrated biosecurity strategies, scientific storage expansion, and adoption of biological and precision pest management technologies.

Table 2. Estimated Production Losses and Economic Costs Attributable to Insect Pests in India (2023–24)

Crop Group	Production (Mt)	Price (₹/tonne)	10% Loss (Mt)	Value @10% Loss (₹ crore)	20% Loss (Mt)	Value @20% Loss (₹ crore)
Rice (Paddy)	137.83	21,830	13.78	30,066	27.57	60,132
Wheat	113.29	23,210	11.33	26,307	22.66	52,614
Maize	37.67	15,000	3.77	5,650	7.53	11,300
Coarse Cereals (Nutri Grains)	56.94	14,000	5.69	7,971	11.39	15,942
Pulses (Total)	24.25	70,460	2.42	17,084	4.85	34,169
Oilseeds (Total)	39.67	50,450	3.97	19,999	7.93	39,998
Cotton (bales → Mt)	5.53	66,200	0.55	3,659	1.11	7,318
Sugarcane	453.16	3,470	45.32	15,728	90.63	31,456
Fruits	112.08	25,000	11.21	28,020	22.42	56,040
Vegetables	205.80	8,000	20.58	16,464	41.16	32,928
Total	—	—	**118.62**	**1,70,948**	**237.24**	**3,41,897**

Source: Calculated from base data, Agricultural Statistics at a Glance, 2025

3.2 Emerging and Re-emerging Pest Complexes

Recent years have witnessed the emergence of several invasive and highly destructive pests that have tested the resilience of India's pest management infrastructure. Among these, the Fall Armyworm (*Spodoptera frugiperda*) invasion in 2018 marked a turning point in national pest surveillance and response systems. Initially confined to maize, the pest rapidly adapted to sorghum and sugarcane across more than twenty states, causing substantial yield losses (Prasanna et al, 2021). Similarly, the Black Thrips (*Thrips parvispinus*) outbreak since 2023 has severely affected chilli crops in Andhra Pradesh, Telangana, and Karnataka, leading to export rejections and income losses for smallholder farmers (Shetty et al., 2024).

Other recurring pests such as the rugose spiralling whitefly (*Aleurodicus rugioperculatus*), the citrus leaf miner (*Phyllocnistis citrella*), and *Phalaris minor* in wheat systems demonstrate the persistent challenge of resistance evolution under high pesticide pressure (MoA&FW, 2024). Weeds such as *Echinochloa crus-galli* and *Cyperus rotundus* have developed herbicide tolerance due to repetitive use of similar chemical modes of action. Concurrently, fungal and bacterial pathogens including *Xanthomonas oryzae* (bacterial blight of rice) and *Phytophthora infestans* (late blight of potato) continue to cause substantial losses under altered temperature and humidity regimes (FAO, 2022).

These outbreaks underscore the inadequacy of reactive chemical-based control systems and the urgency of developing predictive, biologically integrated, and digitally supported approaches. The recurrence of invasive species also highlights the vulnerability of India's biosecurity mechanisms and the need for genomic surveillance, risk assessment, and transboundary pest information sharing.

3.3 Pesticide Use Patterns and Regional Disparities

India's pesticide consumption averages around 0.6 kilograms per hectareconsiderably lower than the global average of 3–11 kilograms per hectarebut regional variations remain stark (FICCI, 2024). The Jammu and Kashmir region record the highest pesticide intensity, often exceeding 2.5 kilograms per hectare, while eastern and northwestern states of Punjab and Haryana use less than 0.7 kilograms per hectare(Muniyappa et al., 2025) (Table 3). Table 3 summarizes national pesticide consumption trends, including the share of bio-pesticides and leading states with highest use. The data show increasing pesticide dependence in intensive farming states, with gradual adoption of bio-based alternatives, highlighting regional disparities in pest management approaches. These disparities reflect differences in cropping patterns, pest pressure, and extension outreach rather than rationalized input use.

Despite moderate overall consumption, pesticide misuse remains widespread. Studies indicate that over 60 percent of farmers rely primarily on private dealers for pest control advice, often leading to the indiscriminate use of chemical mixtures without considering pest thresholds orenvironmental impacts (DPPQS, 2025). This trend has resulted in multiple negative outcomes, including resistance development, non-target toxicity, pollinator decline, and food residue contamination. Substandard or counterfeit pesticides further exacerbate the issue, with approximately 15–20 percent of marketed products failing to meet quality standards (Barwant et al., 2025).

Table 3. Trends in Pesticide Consumption in India (2015–2024)

Year	Pesticide Consumption (000 tonnes, technical grade)	Bio-pesticide Share (%)	States with Highest
2015–16	61.2	2.1	Punjab, Haryana, Maharashtra
2018–19	63.3	3.4	Punjab, Uttar Pradesh, Gujarat
2020–21	65.9	4.6	Punjab, Maharashtra
2022–23	67.4	5.8	Punjab, Telangana, Haryana
2023–24	68.1	6.3	Punjab, Madhya Pradesh, Maharashtra

Source: MoA&FW, 2024

Figure 4 presents the temporal trend in pesticide and bio-pesticide usage. It reveals a gradual increase in total pesticide use alongside a modest but steady rise in bio-pesticide adoption. The trend indicates growing awareness of eco-friendly pest management, though chemical dependence still dominates in several regions.

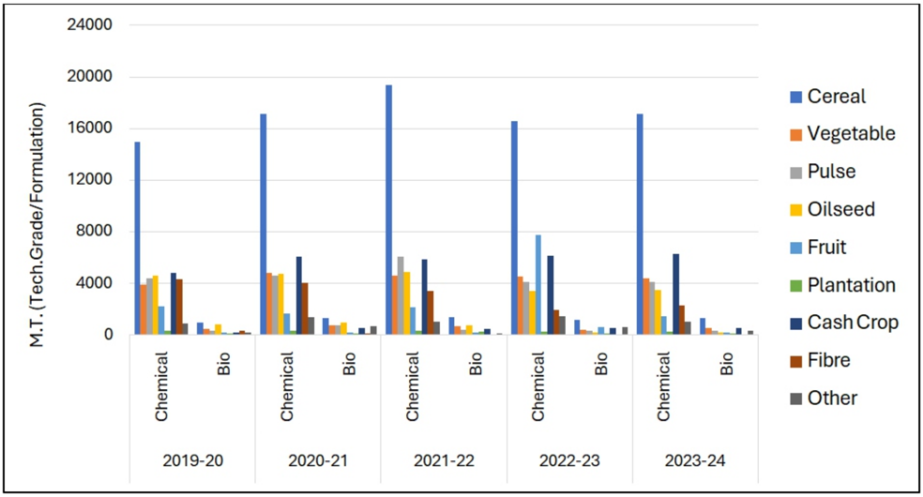

Figure 4: Trends in Pesticide and Bio-pesticide Consumption.
Source: https://ppqs.gov.in

A comparative analysis of regional pesticide use and biotic stress patterns reveals that higher pesticide intensity does not necessarily correlate with better pest control outcomes. Instead, regions with stronger advisory systems and higher adoption of biological inputs tend to report more stable yields and reduced pest outbreaks. This finding underscores the critical role of institutional capacity, input authenticity, and farmer education in achieving sustainable pest management.

3.4 Institutional Fragmentation and Policy Gaps

The governance of pest management in India remains distributed across multiple agencies with overlapping jurisdictions. The Central Insecticides

Board and Registration Committee (CIB&RC) regulates product registration, the ICAR and SAUs undertake research and validation, the Department of Agriculture & Farmers Welfare (DAC&FW) oversees implementation, and NABARD provides financial support for infrastructure and innovation. However, the lack of horizontal coordination among these entities has resulted in administrative duplication, slow response to pest outbreaks, and inadequate field-level monitoring (MoA&FW, 2024). Table 4 compares bio-input regulation across India, the EU, the USA, and Japan. It indicates that India's proposed framework is evolving toward international best practices but still lacks mandatory digital traceability and harmonized registration timelines, calling for regulatory modernization.

Table 4. Comparative Regulatory Framework for Bio-Inputs

Country/Region	Registration Duration (Years)	Bio-Input Categories Covered	Digital Traceability Mandated
India (Proposed)	2–3	Biopesticides, biofertilizers, biostimulants	Under development
EU	1–2	All biological products	Yes
USA	1–3	Biopesticides, biocontrol agents	Yes
Japan	<1	Microbial & natural products	Yes

Source: OECD, 2023; MoA&FW, 2024

Despite the establishment of seventy State Pesticide Testing Laboratories and three national centers, quality enforcement remains inconsistent. Reports suggest that nearly one-third of bio-stimulant formulations in the market are either spurious or unregistered (Choubey, 2025). Additionally, while the National Pest Surveillance System (NPSS) has made progress in AI-based monitoring, its coverage remains limited to pilot regions, preventing real-time decision-making at the national scale (MoA&FW, 2025). The fragmented legal environment with separate regulations for pesticides, fertilizers, and bio-inputscreates both compliance burdens for innovators and confusion among users.

To overcome these constraints, policy convergence is essential. An integrated institutional architecture, such as the proposed National Council for Biotic Stress Management (NCBSM), could serve as a coordination platform linking research, regulation, and implementation. This would facilitate unified standards, shared data repositories, and harmonized extension efforts across central and state levels.

3.5 Technological and Scientific Innovations

Modern science has revolutionized the landscape of pest and disease management, enabling the shift from chemical dependence to ecological and digital precision. Genetic and molecular innovations such as CRISPR-Cas9 gene editing and RNA interference (RNAi) have allowed researchers to manipulate pest-resistance pathways and suppress pest populations through gene silencing (OECD, 2023). In India, ICAR and DBT-funded projects have successfully developed blast-resistant rice and rust-resistant wheat varieties through genome editing, while transcriptomic research at ICAR–NBAIR has enhanced the efficacy of microbial biocontrol agents (ICAR–NBAIR, 2024). Table 5 provides an overview of cutting-edge technologies such as gene editing, AI-based pest forecasting, drones, and metagenomics showing their institutional adoption and policy relevance. It demonstrates India's scientific capacity and the need for enabling policies to mainstream these tools.

Table 5. Emerging Technological Tools for Biotic Stress Management

Innovation	Application Area	Institutional/ Industry Adoption	Policy Relevance
CRISPR-Cas Gene Editing	Resistance breeding in major crops	ICAR, DBT, NRRI, IIWBR	Requires gene-editing guidelines distinct from GMOs
AI-based Pest Forecasting Models	Early warning, outbreak prediction	ICAR–NCIPM, startups	Integrate with NPSS, insurance, and extension
Drone-Based Application	Precision spraying, bio-input delivery	8+ state pilots, private sector	Scale through AIF, FPO-based drone hubs
Metagenomic Diagnostics	Pathogen detection, pest ID	ICAR–NBAIR, SAUs	Strengthen quarantine and bio-surveillance
Hyperspectral Imaging & IoT Sensors	Real-time stress mapping	Agri-tech innovators	Enable climate-smart advisory
Bioagents, Botanicals, and Pheromones	Biological control & IPM	Public-private consortia	Include in procurement and subsidy schemes

(Sources: FAO, 2023; ICAR–NBAIR, 2024; MoA&FW, 2024; OECD, 2023)

Digital technologies are transforming pest surveillance and decision-making. The National Pest Surveillance System (NPSS) employs artificial intelligence and machine learning algorithms for real-time pest identification from trap and field images. Drones have been approved for the aerial application of seventy-nine pesticide formulations, including biological products, significantly improving precision and safety (MoA&FW, 2024). Remote sensing and hyperspectral imaging are being used to detect crop stress before visual symptoms appear, enabling preventive interventions. These technologies collectively mark a transition from conventional pest control to predictive, precision-oriented, and resource-efficient management systems.

However, innovation uptake remains slow due to rigid regulatory procedures, limited investment, and the absence of multi-location validation mechanisms. Bridging these gaps requires a national strategy that links scientific research with market and policy ecosystems, ensuring that laboratory innovations translate effectively to field-level impact.

3.6 Biological Control and Eco-Friendly Inputs

Biological control forms the foundation of sustainable pest management, leveraging natural enemies and beneficial microorganisms to regulate pest populations. India's long-standing research on biocontrol agents such as *Trichoderma harzianum*, *Beauveria bassiana*, and *Metarhizium anisopliae* has resulted in numerous registered products; however, their market share remains below five percent (ICAR–NBAIR, 2024). The constraints include inconsistent product quality, short shelf life under tropical conditions, and limited farmer awareness.

Recent advances focus on microbial consortia that combine multiple beneficial strains, such as *Trichoderma* and *Pseudomonas fluorescens*, to enhance performance across soil and foliar pests. Similarly, bio-stimulants derived from seaweed extracts, neem oil, and chitosan are gaining popularity for their plant defense–enhancing properties. India has also begun commercializing entomopathogenic nematodes for soil pest control under DBT–ICAR collaborations (ICAR–NBAIR, 2017).

Table 6. Status and Growth Trends of Biological Control and Eco-Friendly Inputs in India

Parameter	2018–19	2020–21	2022–23	2023–24	Key Observations / Source
Registered biopesticide formulations (nos.)	970	1,120	1,265	1,340	Steady rise in registrations under CIB&RC; demand driven by organic & IPM programmes (MoA&FW, 2024)
Share of biopesticides in total pesticide use (%)	3.4	4.6	5.8	6.3	Gradual increase but still <10 % of market (DPPQS, 2025)
Market size of bio-inputs (biopesticides + biofertilizers + biostimulants) (₹ crore)	780	960	1,120	1,250	Industry growing @ 15–18 % annually (ICAR–NBAIR, 2024; Shimpi et al., 2023)
Estimated production capacity of biocontrol agents (tonnes per year)	12,000	14,500	16,800	18,200	Includes *Trichoderma*, *Pseudomonas*, *Beauveria*, *Metarhizium* (ICAR–NBAIR, 2024)
Active public / private production units (nos.)	210	235	260	275	Mix of ICAR, SAUs, FPOs & SMEs (NCIPM Database, 2024)
Area under IPM / biocontrol coverage (million ha)	5.6	6.8	7.9	8.5	Expansion through NMSA & PKVY schemes (MoA&FW, 2024)
Estimated reduction in chemical pesticide use due to bio-inputs (%)	4.0	5.5	6.7	7.5	Gradual substitution trend (OECD, 2023; FAO, 2023)

Source: Compiled from ICAR–NBAIR (2024), Directorate of Plant Protection, Quarantine & Storage (2025), Ministry of Agriculture & Farmers Welfare (2024), FAO (2023), and OECD (2023).

The data presented in Table 6 indicate a consistent expansion of biological and eco-friendly inputs in India's pest management landscape. Registrations of biopesticide formulations and the overall bio-input market have shown steady growth, reflecting rising policy support and farmer awareness under schemes such as NMSA and PKVY. Despite accounting for only about 6 percent of total pesticide use, the rapid annual growth rate of 15–18 percent underscores the sector's potential for large-scale substitution of chemical inputs. Increasing production capacities and area under Integrated Pest Management (IPM) signal a gradual but significant transition toward sustainable and ecosystem-based pest control, aligning with India's long-term vision for green and biosecure agriculture. To strengthen adoption, it is essential to establish National Bio-Validation and Quality Control Laboratories (NBVQCLs) and promote decentralized bio-resource centers managed by FPOs and SHGs. Government procurement and subsidy inclusion for biocontrol products under schemes such as the National Mission on Sustainable Agriculture (NMSA) and Paramparagat Krishi Vikas Yojana (PKVY) can provide strong policy support.

Biocontrol not only reduces ecological risks but also aligns with India's commitment to responsible consumption and production under SDG 12. Its success, however, depends on scaling up production capacity, ensuring product integrity, and fostering trust through regulatory transparency and farmer education.

3.7 Modern Precision Technologies and Drone-Based Pest Management

The emergence of precision agriculture technologies has revolutionized pest and disease management in Indian agriculture. Precision tools such as drones, remote sensing, geographic information systems (GIS), and the Internet of Things (IoT) have made it possible to monitor crop health, identify stress zones, and apply inputs with unprecedented accuracy. These technologies allow for real-time detection of pest outbreaks, early warning generation, and targeted control measures, significantly reducing input waste and environmental contamination. Precision pest management thus represents a critical shift from calendar-based spraying to data-driven, need-based interventions, enhancing both efficiency and sustainability.

Drone-based applications have gained rapid momentum in India since their official approval by the Directorate of Plant Protection, Quarantine & Storage (DPPQS) in 2022. Currently, over seventy-nine pesticide formulations, including several biological products, have been approved for aerial spraying (MoA&FW, 2024). Drones facilitate uniform application, minimize operator exposure, and enable timely responses during pest epidemics. They also play an essential role in difficult terrains and large-scale operations such as monitoring invasive pest infestations and applying microbial biocontrol agents over extensive areas. Pilot initiatives under the Sub-Mission on Agricultural Mechanization (SMAM) and the Agricultural Infrastructure Fund (AIF) have already demonstrated the cost-effectiveness of drone-based pest management for crops like paddy, cotton, and sugarcane.

Integration of precision tools with artificial intelligence (AI) and machine learning (ML) has further enhanced the capacity for predictive pest management. AI-driven image analytics and hyperspectral sensors mounted on drones or satellites can detect early stress signatures invisible to the naked eye, allowing preventive interventions before pest populations reach economic thresholds. The National Pest Surveillance System (NPSS) is currently working toward integrating such digital platforms with pest forecasting and advisory systems. Linking real-time data with crop insurance and market intelligence systems can strengthen resilience against pest-induced yield losses while improving decision-making across scales.

Despite these advances, widespread adoption of precision and drone-based systems remains limited by high capital costs, regulatory constraints, and the lack of trained operators. Institutional support through capacity-building programs, subsidies, and shared-service models can address these barriers. Farmer Producer Organizations (FPOs), custom hiring centers, and agri-tech start-ups can act as local hubs for drone services, ensuring access and affordability. Standard operating procedures (SOPs) for safe and efficient drone use, combined with digital traceability and field validation of AI models, are essential for ensuring environmental safety and regulatory compliance.

Overall, the integration of precision agriculture, drone technologies, and digital analytics marks a pivotal transformation in India's pest management strategy. By enhancing input efficiency, reducing chemical dependency, and improving farm-level resilience, these innovations align closely with the national agenda for climate-smart, sustainable, and biosecure agriculture.

3.8 Integration of Indigenous and Traditional Knowledge

Indigenous and traditional ecological knowledge has long played a vital role in pest management within Indian farming systems. Practices such as seed storage using neem leaves, trap cropping with marigold or mustard, intercropping, and ash dusting exemplify low-cost, eco-friendly solutions that have sustained productivity for generations (Reddy, 2017). Preparations such as *Panchagavya* and *Jeevamrutha* have been widely used as bio-stimulants to promote plant vigor and resistance.

However, these traditional methods often lack standardization and scientific validation, limiting their acceptance within formal policy frameworks. Integrating traditional wisdom with modern science can help bridge this gap. Participatory research involving farmers, local institutions, and research centers can help document, validate, and scale proven indigenous practices. Additionally, promoting women's self-help groups (SHGs) as local bio-input entrepreneurs can strengthen rural livelihoods while enhancing sustainability.

This integration not only preserves cultural knowledge but also reinforces social inclusiveness and community ownership of pest management, an essential component of resilient and equitable agricultural systems.

4. Conclusion and Policy Implications

4.1 Synthesis of Key Findings

The analysis presented in this policy paper underscores that India's agricultural sector stands at a crucial crossroads. Biotic stresses like pests, pathogens, weeds, and microbial contaminantsremain a major constraint to achieving food security, reducing yield losses, and maintaining environmental sustainability. Despite advancements in integrated pest management, biological control, and digital surveillance, the persistence of invasive pests, resistance development, and ecological imbalance highlight the systemic limitations of existing governance and technological frameworks (Angon et al., 2023; FAO, 2022).

The evidence suggests that the current regulatory and institutional structures are inadequately equipped to respond to emerging biosecurity threats. Fragmented responsibilities, outdated legislation, and weak inter-agency coordination impede innovation and timely response. The Insecticides Act (1968) and Fertilizer Control Order (1985), conceived in an earlier chemical-intensive era, no longer reflect the scientific and commercial realities of modern agriculture (MoA&FW, 2024). Furthermore, the proliferation of unregulated bio-stimulants and counterfeit products points to weak enforcement mechanisms and the need for harmonized oversight.

On the positive side, India has significant opportunities to reposition itself as a global leader in sustainable pest management. The convergence of scientific innovationssuch as genomics, digital agriculture, and bio-based solutionsprovides a foundation for an ecological transformation of pest management practices (OECD, 2023). Growing consumer awareness, expanding markets for residue-free produce, and India's commitments under the Sustainable Development

Goals (SDGs) collectively create a favorable policy environment for transition.

To realize this potential, however, India must shift from fragmented, reactive measures to a proactive, system-wide approach that integrates science, governance, and societal participation. This necessitates a unified and forward-looking policy architecture capable of addressing regulatory, institutional, and technological gaps while incentivizing sustainable behavior across the agricultural value chain.

4.2 Policy Implications

The findings of this study have several implications for agricultural policy, governance, and institutional reform in India. Table 7 outlines pesticide intensity and Integrated Pest Management (IPM) adoption rates across different regions of India. It shows that southern and northeastern states have higher IPM adoption, while northwestern regions remain heavily pesticide-dependent, implying the need for region-specific strategies.

Table 7. Distribution of Pesticide Use and IPM Adoption by Region

Region	Pesticide Use (kg/ha)	IPM Adoption (%)	Remarks
North-West	1.2	35	High intensity, cotton–paddy systems
Central	0.8	45	Mixed cropping, rising bio-input use
East	0.4	50	Low chemical use, strong FPO presence
South	0.7	60	Higher IPM adoption in horticulture
North-East	0.3	65	Traditional pest management domain

Source: Ministry of Chemicals and Fertilizers, Govt. of India

Regulatory Modernization:

There is an urgent need to establish a comprehensive and unified Bio-Input Regulation Act that harmonizes the governance of biopesticides, biofertilizers, and bio-stimulants under a single framework. This Act should streamline registration, approval, and quality control processes through a risk-based, time-bound system, replacing fragmented regulations that currently operate under multiple ministries (Reddy, 2025). Digital traceability platforms should be mandated for all registered products to ensure transparency, authenticity, and real-time monitoring.

Institutional Convergence and Governance:

Effective pest management requires the establishment of a National Council for Biotic Stress Management (NCBSM) as a central coordinating body. This council should include representatives from ICAR, DAC&FW, DBT, MoEFCC, NABARD, and State Agricultural Universities to promote cross-sectoral coordination. Its functions would include overseeing pest surveillance, policy implementation, biosecurity preparedness, and funding mechanisms. Such an institution could serve as a nodal platform for evidence-based decision-making, aligning scientific research with field-level execution. Table 8 consolidates major policy instruments, their governing agencies, strengths, and identified gaps. It provides a clear overview of how outdated regulations and fragmented responsibilities limit progress, thereby justifying the proposed unified Bio-Input Regulation Act and NCBSM.

Table 8: Key Policy Instruments and Identified Gaps in Biotic Stress Management

Policy Instrument	Year	Governing Agency	Key Strength	Identified Gap
Insecticides Act & Rules	1968–1971	MoA&FW (CIB&RC)	Comprehensive chemical pesticide safety evaluation	Outdated; inadequate scope for bioagents, drones, and consortia
Fertilizer Control Order (FCO)	1985	MoA&FW	Promotes biofertilizers and biostimulants	No harmonization with CIB&RC; duplication in standards
National IPM Program	1992	ICAR–NCIPM	Promotes integrated pest management	Weak adoption, limited field-level manpower
Plant Quarantine (Regulation of Import into India) Order	2003	DPPQ&S	Prevents pest entry through trade pathways	Limited genomic surveillance and diagnostic capacity
National Pest Surveillance System (NPSS)	2021	DAC&FW	AI-based pest monitoring and real-time advisory	Still in pilot phase; limited integration with state systems

Sources: MoA&FW, 2024; OECD, 2023

Strengthening Biosecurity Infrastructure:

India's vulnerability to invasive pests and diseases necessitates the strengthening of national and regional biosecurity mechanisms.

Establishing Genomic Surveillance Centers and Rapid Diagnostic Laboratories at border points and key agricultural hubs would allow early detection and containment of exotic pests. Regular pest risk assessments, coordinated with international agencies such as FAO and IPPC, should be institutionalized to ensure preparedness.

Promotion of Biological and Eco-Friendly Inputs:
Expanding the use of biological control agents and bio-stimulants is crucial for sustainable pest management. The government should create a dedicated Bio-Agri Mission under the National Mission on Sustainable Agriculture (NMSA) to promote biocontrol enterprises, provide fiscal incentives for production infrastructure, and include registered bio-products under subsidy schemes. Inclusion of Farmer Producer Organizations (FPOs), women-led SHGs, and start-ups as bio-resource centers will enhance rural entrepreneurship and decentralize production (ICAR–NBAIR, 2024).

Capacity Building and Knowledge Systems:
Strengthening human capacity is central to the success of integrated pest management. The existing extension network like Krishi Vigyan Kendras (KVKs), Farmer Field Schools (FFSs), and ATMA programsshould be revitalized with specialized training modules on IPM, biosecurity, and digital decision tools. A cadre of para-extension professionals trained in pest diagnostics, safe pesticide handling, and bio-agent production should be developed at the village level. Targeted inclusion of women and youth will improve both outreach and innovation diffusion (FAO, 2022).

Financial Incentives and Ecosystem Payments:
To motivate behavioral change among farmers, the government should introduce Ecosystem Service Payments (ESPs) for farmers who adopt

IPM and organic pest control practices. These payments can be modeled on the "green credit" framework promoted by NABARD and linked to quantifiable ecosystem benefits such as reduced pesticide load, pollinator enhancement, or soil health improvement. Insurance-linked incentives could also be designed, rewarding farmers who maintain pest management plans aligned with sustainable standards.

Digital Transformation and Data Governance:
The expansion of digital agriculture presents opportunities to transform pest management. A National Biotic Stress Dashboard (NBSD) should be established to consolidate data from pest surveillance, meteorological models, and remote sensing for real-time advisory generation. Integration with the Digital Agriculture Mission can ensure that pest alerts and advisories reach farmers through mobile platforms in vernacular languages. Additionally, open-access data repositories will facilitate collaborative research and foster innovation by start-ups and academic institutions.

Monitoring, Evaluation, and Adaptive Governance:
An effective monitoring and evaluation system is vital to ensure the accountability of pest management interventions. Performance indicators should be developed for pest incidence reduction, bio-input adoption rates, residue compliance, and biodiversity enhancement. Annual Pest Management Report Cards could be published at district and state levels to track progress and identify gaps. Adaptive governance mechanisms, incorporating feedback loops between research institutions, policymakers, and farmer organizations, would ensure continuous refinement of policies in response to changing field realities.

4.3 Strategic Roadmap for Implementation

The successful implementation of the proposed policy framework requires a phased, multi-level approach. In the short term (1–2 years), efforts should focus on harmonizing existing regulations, strengthening pest surveillance, and initiating pilot programs on biosecurity and biocontrol. Medium-term priorities (3–5 years) should include the establishment of the NCBSM, digital infrastructure development, and scaling of bio-input enterprises. Long-term goals (beyond five years) should aim at full integration of pest management within national sustainability strategies, including the National Mission on Natural Farming and the Climate Resilient Agriculture Program.

Collaboration among ministries, private industry, and civil society organizations will be key to sustaining these efforts. Financial support from NABARD, convergence with CSR programs, and international partnerships for capacity building can further strengthen implementation. Importantly, continuous farmer engagement and transparency in governance will be essential to ensure adoption and trust at the grassroots level. The phased roadmap presented in Table 8 outlines a sequential approach for integrating bio-input–based pest management into India's agricultural policy and practice. The framework emphasizes short-term harmonization of existing regulations, medium-term capacity and financial system development, and long-term consolidation through institutional convergence and global alignment. By linking research, governance, finance, and extension mechanisms, the roadmap provides a structured pathway to transition from pilot initiatives to nationwide adoption of sustainable pest management practices. It highlights the need for inter-ministerial collaboration, robust monitoring systems, and continuous stakeholder engagement to ensure lasting impact and scalability.

Table 9: Phased Roadmap for Policy Integration and Scaling of Bio-Input Based Pest Management in India

Phase	Duration	Key Actions
Phase I – Policy Integration and Infrastructure (Year 1–2)	- Enact Bio-Input Regulation Act. - Launch NCBSM and NBSD. - Expand NPSS to all states. - Identify regional biosecurity hubs.	MoA&FW, DAC&FW, ICAR, DBT
Phase II – Capacity and Financial Systems (Year 2–4)	- Operationalize NABARD's GLC and ESP schemes. - Establish 100 FPO-based Bio-Resource Centers (BRCs). - Train 10,000 Community Pest Scouts (CPS).	NABARD, ICAR–SAUs, State Depts., KVKs
Phase III – Mainstreaming and Scale (Year 4–6)	- Integrate IPM and biosecurity modules into all KVKs and FFS curricula. - Full deployment of NBSD with real-time open data access. - Establish carbon-linked pest management markets.	NCBSM, NITI Aayog, MoEFCC
Phase IV – Consolidation and Global Alignment (Year 6–10)	- Export promotion for certified bioproducts. - Integrate with FAO and SAARC biosecurity networks. - Continuous impact evaluation and policy refinement.	MoA&FW, MEA, FAO, SAARC Secretariat

4.4 Concluding Remarks

India's agricultural transformation depends on its ability to manage biotic stresses sustainably and strategically. The integrated policy framework proposed in this paper provides a pathway toward achieving ecological balance, economic viability, and social inclusiveness in pest management. By embracing modern science, harmonizing institutions, and empowering farmers, India can reduce its dependency on chemical inputs, restore agroecosystem resilience, and strengthen food and environmental security.

In the long term, the success of biotic stress management will hinge on sustained political commitment, public–private collaboration, and participatory governance. The transition from reactive pest control to preventive biosecurity represents not only a scientific necessity but also a national priority for ensuring the resilience and competitiveness of Indian agriculture in the decades ahead.

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Appendix A

नाबार्ड

राअस्ट्रैप्रसं
NIASM

NIBSM

TWO DAYS BRAINSTORMING SESSION

On

"POLICY PAPER ON BIOTIC AND ABIOTIC STRESS MANAGEMENT IN INDIAN AGRICULTURE"

July 21 and 22, 2025

Inaugural Session Programme **Venue: Auditorium, ICAR-NIBSM, Raipur**

Time	
09:30 AM – 10:00 AM	Registration and Plantation by Guests
10:00 AM – 10:05 AM	ICAR Song by AKMU
10:05 AM – 10:10 AM	Lighting of Lamp
10:10 AM – 10:15 AM	Introduction of Dignitaries on Dais and Welcome Address Dr. A. Amarender Reddy, Joint Director, SCHPSR, ICAR-NIBSM
10:15 AM – 10:30 AM	Floral Welcome and Felicitation of Dignitaries on Dais
10:30 AM – 10:40 AM	Dr. D. K. Marotia, President, Indian Society of Agricultural Economics (ISAE), Mumbai
10:40 AM – 10:50 AM	Dr. K. Sammi Reddy, Director, ICAR-NIASM, Baramati
10:50 AM – 11:00 AM	Distinguished Guest Address Dr. HC Sharma, Ex-Vice Chancellor, HPKV, Palampur, HP
11:00 AM – 11:10 AM	Distinguished Guest Address Dr.PK Chakrabarty, Ex-ADG (PP&B); Member, ASRB, New Delhi
11:10 AM – 11:20 AM	Chief Guest's Address Dr. Gyanendra Mani, Chief General Manager, NABARD, Raipur
11:20 AM – 11:25 AM	Release of Publications (e.g., Atlas)
11:25 AM – 11:30 AM	Chairperson's Address Dr. P.K. Rai, Director, ICAR-NIBSM, Raipur
11:30 AM – 11:40 AM	Vote of Thanks Dr. Kamal Vatta, Secretary, ISAE
11:35 AM – 11:45 AM	High-Tea

Appendix B

Technical Committee of Brainstorming Workshop on Biotic and Abiotic Stress Management and Policy Issues in Indian Agriculture (July 21-22, 2025)

Day 1: 21st July 2025

Session I: Scientific, Technological, and Regulatory Innovations in Biotic Stress Management	
Chair	**Dr. H. C. Sharma, Former Vice Chancellor, HPKV, Palampur, HP**
Co-Chair	Dr. K. K. Mondal, Dr. K. Srinivas
Convener	Dr. Binod Kumar Choudhary
Rapporteur	Dr. Arkaprava, Dr. R. K. Murali Baskaran

Session II: Policy, Institutional, and Regulatory Strategies for Scaling Biotic Stress Management	
Chair	**Dr. P. K. Chakrabarty, Former ADG (PP&B); Member, ASRB, New Delhi**
Co-Chair	Dr. P. K. Agrawal/ Dr. M. Parasuramaiah
Convener	Dr. P. N. Sivalingam
Rapporteur	Dr. Sridhar J., Dr. L. L. Kharbikar

Day 2: 22nd July 2025

Session III: Scientific and Technological Interventions in Abiotic Stress Management	
Chair	**Dr. K.L. Gurjar, Joint Director, DPPQS, Faridabad**
Co-Chair	Dr. Pankaj Sharma/ Dr. (Mrs.) Daisy Basandrai
Convener	Dr. N. P. Kurade, NIASM
Rapporteur	Dr. Mallikarjuna Jeer, Dr. Bhaskar Gaikwad, NIASM

Session IV: Policy, Institutional, and Programmatic Frameworks for Abiotic Stress Resilience	
Chair	**Dr. Anjani Kumar, Senior Research Fellow, IFPRI, New Delhi**
Co-Chair	Dr. Anil Dixit/ Dr. Nalini Ranjan Kumar
Convener	Dr. S. K. Jain
Rapporteur	Dr. Priyanka Meena, Dr. Vinay Kumar

Appendix C

Organizing and Execution Committees of the Brainstorming Workshop

S. No.	Committee	Chairman	Members
1.	**Transport and Vehicle Management Committee**	Dr. Vinay Kumar, Principal Scientist	Dr. Mallikarjuna J. Dr. Vinod Kumar Wasnik
2.	**Food Committee**	Dr. K. C. Sharma, Principal Scientist	Dr. P. Mooventhan
			Dr. Priyanka Meena
			Mr. Malay Bisht
3.	**Accommodation Committee**	Dr. L. L. Kharbikar, Senior Scientist	Dr. Sandeep Adavi B.
			Mr. Malay Bisht
4.	**Hall Management Committee**	Dr. Binod Choudhary, Principal Scientist	Dr. Shravani Sanyal
5.	**Technical Session Committee**	Dr. S. K. Sharma, Principal Scientist	Dr. Lata Jain
			Dr. Sridhar J.

Appendix D

List of Participants

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