



**International Conference**  
**Advances in Digital Solutions and**  
**Green Technologies in Crop Pest**  
**Management**  
**25-27 February 2026**  
**Venue: Indian Statistical Institute, Kolkata**

**Book of Abstracts**

**Compiled and Edited by**

Matiyar Rahaman Khan  
Shantanu Jha  
Raman K. Walia  
Abhishek Mukherjee  
Mohammad Shariq



Together we will  
protect our crops

**Association for**  
**Advancement in Plant**  
**Protection**

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# International Conference

## Advances in Digital Solutions and Green Technologies in Crop Pest Management

25 to 27 February 2026

*Organized by*

**Association for Advancement in Plant Protection**



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**We look forward to welcoming you to Kolkata for three days of scientific exchange and collaboration.**

## Message

I extend my warmest greetings to each one of you attending International Conference on '**Advances in Digital Solutions and Green Technologies in Crop Pest Management**', being held from 25–27 February 2026 at the prestigious Indian Statistical Institute (ISI), Kolkata.

I warmly congratulate the Association for Advancement in Plant Protection (AAPP), the Local Organizing Committee, and all team members for organizing this timely and significant event. In the face of global challenges such as climate change, emerging pests, pollinator decline, and the need to reduce chemical pesticide use, this conference rightly emphasizes the integration of digital innovations and green technologies for sustainable agriculture.



A recent review of 25 years of Pesticidal Cry1Ab/Ac Fusion Proteins in Crop Protection (*Journal of Crop Health* 2025, 77:55) and the comprehensive program, covering AI-driven pest management, biological control, climate-smart strategies, and youth engagement activities, reflects a strong commitment to interdisciplinary and future-oriented research. Such convergence of science, technology, and sustainability is essential for building resilient cropping systems and ensuring food security.

I wish all speakers, participants, and young scholars a highly productive conference. May the deliberations foster meaningful collaborations, inspire innovation, and contribute significantly to sustainable and climate-resilient pest management for the benefit of humanity and the environment.

Best wishes for a successful and impactful event!

A handwritten signature in blue ink that reads "S. U. Datta".

**Professor Swapan Datta**

NASI Distinguished Professor (H) at Swami Vivekananda Univ, Barrackpore, WB  
Former Deputy Director General (Crop Science) ICAR,  
Former Vice Chancellor Visva Bharti, Shantiniketan,  
Founder Vice Chancellor Biswa Bangla Biswabidyalay, Birbhum, India

## Message

It gives me immense pleasure to know that the Association for Advancement in Plant Protection (AAPP) is organizing a three-day International Conference on 'Advances in Digital Solutions and Green Technologies in Crop Pest Management' from February 25–27, 2026, at the Indian Statistical Institute (ISI), Kolkata.



This conference, organized in collaboration with the prestigious National Academy of Agricultural Sciences (NAAS), New Delhi, comes at a crucial juncture when agriculture is facing the dual challenges of climate change and food security. The theme is exceptionally relevant, focusing on the synergy between cutting-edge digital innovations and sustainable green technologies.

As the President of AAPP, I extend a warm welcome to all delegates, scientists, researchers, and industry professionals participating in this event. I am confident that the discussions and deliberations over these three days will pave the way for groundbreaking solutions in pest management that are both effective and environmentally responsible.

I extend my best wishes to the Organizing Committee for their tireless efforts and wish the conference grand success.

A handwritten signature in blue ink, reading "Asit Kumar Mukherjee". The signature is fluid and cursive.

**Prof. Asit Kumar Mukherjee**

President  
Association for Advancement in Plant Protection (AAPP)

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## Digital Solutions and Green Technologies in Crop Pest Management: Biological Control and Precision Pest Management in Cotton

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**MEGHA N. PARAJULEE**

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Digital technologies such as Satellite Imagery, Drones, Global Positioning System, Geographic Information System, Artificial Intelligence, and Internet of Things sensors work with green technologies such as habitat diversification, biological control, biopesticides, regenerative farming, and controlled-environment agriculture to manage crop pests with greater precision, reducing chemical use and environmental impact. Digital tools provide real-time data for early pest detection and variable rate application for site-specific management, while green technologies offer more sustainable, environmentally compatible alternatives to broad-spectrum pesticides.

Precision pest management is a targeted approach that is based on spatial and temporal variability within crop fields, which helps in monitoring, predicting, and managing pest populations effectively. There is often an aggregated distribution of insects in the field because of crop conditions and environmental factors, and hence, spatial mapping is very critical. Unlike the conventional method of management, it uses modern technologies such as satellite imagery, drones, GPS, GIS, and others. Different vegetation indices, including NDVI, are key indicators to determine plant health and vigor. NDVI is regarded as the proxy of green biomass and is related to canopy photosynthesis and vegetation biodiversity. While some spatial associations have been established between areas of high cotton growth and tarnished plant bug activities, the relationship between NDVI and pest presence is not well understood. Use of excessive resources and inefficient delivery of agriculture input render direct economic loss while surface runoff, nutrient leaching, pesticide drift and water contamination, and other unintended consequences of injudicious use of resources contribute to environmental degradation. Development of techniques that increase crop production and optimize pest management through increased input efficiency and reduced environmental losses to maintain economically and environmentally sustainable production system is vital in today's agriculture.

A long-term study comprised of laboratory and field studies demonstrated significant predator-induced biocontrol in cotton agroecosystems to avoid the need for pesticide intervention altogether. In the laboratory, the cotton aphid, *Aphis gossypii*, predation rate of ladybug, *Hippodamia convergens*, averaged 40, 100, 150, and 200 aphids within 1, 4, 8, and 24 h, respectively, at maximum density of 200 aphids per predator. Predators showed a curvilinear feeding response in relation to total available time, indicating that ladybugs have

the potential to suppress larger populations of aphids through continuous feeding by regulating their predation efficiency during feeding. An analysis of age-specific mortality in absence of prey revealed that ladybugs could survive for an extended period (>2 weeks) without prey. The ability of a predator to survive without prey delays or prevents the rebound of pest populations that is a significant factor in natural biological control. A 2-year field sampling of cotton arthropod predators showed that spiders (27%) were the most dominant predators followed by convergent lady beetles (23.5%), hooded beetles (13.5%), minute pirate bugs (11%), green lacewings (9.5%), bigeyed bugs (7.5%), scymnus beetles (3%), soft-winged flower beetles (2%), damsel bugs (1.5%), and assassin bugs (1.5%) that collectively suppressed cotton aphid field populations below economic thresholds. A field cage study showed that one ladybug adult per plant released at prey density of one aphid per leaf kept the aphid population below economic threshold for the entire growing season. Because early colonization of natural enemies suppressed the aphid population below economic thresholds for the entire season, a relay intercropping of winter and spring strip crops with cotton was used to conserve and enhance predators of the cotton aphid for early season colonization in cotton. The intercrops acted as a reservoir for predators during the non-cotton season; these intercrops 'relayed' aphid predators from canola and wheat in the winter to sorghum in the spring and finally to cotton in the summer. Average aphid abundance was lower in relay intercropped cotton than in isolated cotton. Average predator numbers were higher in relay intercropped cotton than in isolated cotton, and predators appeared in higher numbers earlier in the summer in relay intercropped cotton than in isolated cotton. Results from this study demonstrated that where cotton is grown without insecticides, relay intercropping aids the early arrival and continuous population increase of predators in cotton, thereby reducing numbers and postponing the initial population increase of the cotton aphid. Avoiding the use of early season insecticides and managing naturally diversified habitats are the demonstrated green technologies in suppressing cotton aphids in Texas cotton.

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## Digital Assessment of Leaf Curl Infection Risk for Strategic Management Options

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Leaf curl disease, caused by whitefly transmitted Chilli leaf curl virus (ChiLCV), is a major in chilli. Assessment of infection risk is problematic due to overlapping symptoms caused by mites and thrips. For field surveillance, image-based systems are developed. The lightweight SCA-MobiPlant classifier, integrating coordinated attention with MobileNetV3-Small, achieved 99.64% accuracy at 89 FPS using only 0.68 million parameters, reliably discriminating healthy, mite-affected, and virus-infected plants, while a semi-supervised annotation strategy reduced expert labelling effort by 30–50%. An advanced YOLOv9t-DyE + MobileSAM framework further enabled real-time detection, symptom discrimination, and pixel-level disease severity estimation, demonstrating robust field performance (POD 0.88, CSI 0.79) and a 12.15-fold reduction in assessment time. Both imaging systems were deployed as Android applications to support on-site diagnosis and disease incidence estimation. The integrated imaging framework is useful in finding epidemiological insights into a practical management of the disease.

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## **Artificial Intelligence (AI) Tools in Entomology**

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Artificial Intelligence (AI) is a wide-ranging field within computer science that enables machines to carry out tasks typically requiring human intelligence. Machine Learning (ML), a branch of AI, allows computers to recognize patterns in data and generate predictions. Deep Learning (DL), a more advanced form of ML, employs artificial neural networks inspired by the human brain to automatically detect, extract, and learn complex features from large datasets. In Entomology, AI-driven tools have become highly valuable for rapid insect identification and detection of pest damage symptoms. They also facilitate monitoring of insect behaviour, evaluation of morphological traits and developmental patterns, and sex determination important for breeding studies. Additionally, AI models aid in conserving insect pollinators and in forecasting pest populations and outbreaks, thereby strengthening early warning and timely management systems. These technologies have transformed traditional entomological research by making it faster, scalable, and more precise. Despite these advances, several challenges persist, including the lack of large, well-validated and balanced entomological datasets; complications arising from field conditions such as variable lighting, occlusion, and overlapping insects; substantial computational requirements; and limited accessibility for smallholder farmers. Overcoming these issues will require coordinated efforts to create open-access image repositories, standardize annotation procedures, and develop lightweight models suitable for mobile platforms. Integration with digital technologies such as Internet of Things (IoT) sensors, unmanned aerial vehicles (UAVs), and cloud-based decision support systems will further expand AI applications in entomology. The scope of digital entomology extends beyond pest management to biodiversity assessment, conservation biology, ecological modelling, and early detection of invasive species. By reducing excessive pesticide dependence, enhancing diagnostic efficiency, and enabling targeted interventions, AI can play a major role in promoting sustainable agriculture and ecological resilience.

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## Towards Automated Nematode Identification: Machine Learning as a New Paradigm in Nematology

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Accurate identification of plant-parasitic nematodes (PPNs) is fundamental to effective pest management, ecological monitoring, and biodiversity studies. Traditional methods based on morphological features demand substantial expertise and are time-consuming, while molecular techniques, though powerful, require specialised infrastructure. In recent years, machine learning (ML), especially deep learning (DL), has emerged as a promising alternative for nematode detection and classification. These models can learn subtle patterns from biological images and provide rapid, consistent predictions even in complex datasets.

This talk will provide an overview of current ML-based approaches in nematode research, including species detection from microscopic images, lifecycle stage recognition, and trait prediction. Drawing on a recent study from our lab, I will illustrate how convolutional neural networks (CNNs) such as AlexNet and VGG16 were trained from scratch to identify root-knot nematodes (*Meloidogyne* spp.) based on perineal pattern images. Our model achieved high classification accuracy (~95%) and incorporated interpretability features (Integrated Gradients), enabling alignment between algorithmic outputs and expert-derived morphological features. This not only enhances model transparency but also builds trust among nematologists.

By reducing reliance on specialised taxonomic expertise and enabling high-throughput screening, machine learning holds transformative potential for diagnostics, surveillance, and sustainable nematode management. I will conclude by outlining key challenges, including data limitations and the "black-box" nature of DL models, and future directions to integrate ML tools in mainstream nematology workflows.

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## Infochemical Research and Technologies from 1870 to 2026: A Retrospect

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When Fabre (1870) placed females of *Saturnia pyri* (Denis and Schiffermuller) in cages and demonstrated the attraction of males towards the females, little did he realize about the significance of his discovery, which later laid the foundation stone for the research and technologies on the infochemicals. With the discovery of "bombykol", later by Adolf Butenant in 1959, the importance and vitality of chemical ecology research was understood. The research techniques and methodologies in the isolation, identification, synthesis and formulation of semiochemicals have been modified and refined over the decades. Pheromones and other allelochemicals have been identified for more than 6000 species of insects. Chemosensory genes including Odorant Binding Proteins (OBP), or Pheromone Binding Proteins (PBP) and Olfactory Receptors (OR) have been deciphered for large number of insects which has prompted the concept of "Reverse Chemical Ecology". Formulation technologies have gained momentum from the rubber septa to the microencapsulated or nano-pheromones or wax based dispensers for the various applications with emphasis on low cost and ease of application. Pheromones and parapheromones have been used for the quarantine monitoring, population estimation, prediction and forecasting of various species of insects. Mass trapping using pheromones and kairomone has been successfully practiced for various species of insects. With the advancement in formulation technologies, the mating disruption technology has been proved as an efficient method for various agricultural pests with little or no dependence on insecticides. Recent developments have demonstrated that the infochemicals can be used for the management of storage grain pests, veterinary pests and urban pests. Biotechnological approach has paved the way for the synthesis of insect pheromones utilizing plants and microbes with assured quality. Volatile sensors are being attempted with emphasis on "Synthetic Nose or Synthetic Antenna" which envisages greater scope in precision farming. Futuristic trends on increasing effective use of semiochemicals in the management of pests as an important component in the organic farming are gaining momentum. However, farmers' trust and adoption depend on the development of cost effective, ease of application and robust technologies with assurance of quality, availability and trust worthiness.

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## **Plant–Insect Chemical Dialogues: Integrating Semiochemical Technologies for Sustainable Pest Management**

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Insect behaviour represents the most sensitive biological readout of plant-insect interactions and provides a powerful entry point for designing green chemistry based, environmentally benign pest management strategies. Contemporary crop protection is transitioning from broad-spectrum chemical suppression to behaviour-modifying, knowledge-intensive interventions that exploit semiochemicals, host plant cues, and ecological interactions. Our work demonstrates that host cues and herbivore-induced plant volatiles (HIPVs) function as shared behavioural attractants for multiple herbivore guilds while simultaneously recruiting natural enemies. Using electrophysiology (GC-EAD), behavioural bioassays, metabolomics, and transcriptomics, we reveal how insects decode plant chemical landscapes to make host-selection decisions. These findings highlight opportunities for designing precision lures, push–pull systems, and selective attract-and-kill platforms that reduce pesticide reliance.

In parallel, we explore microbial mediation of plant signalling and its impact on volatile emission, oviposition behaviour, and larval performance. Integration of behavioural data with chemical profiling enables predictive modelling of pest preference across crop phenological stages. When coupled with digital monitoring tools, smart dispensers, and real-time field analytics, semiochemical deployment can be optimized spatially and temporally for maximal efficacy and minimal ecological disruption.

The translational pathways from laboratory discovery to scalable field deployment, including slow-release formulations, pollinator-safe strategies, and compatibility with biological control are essential for next-generation IPM frameworks. By positioning insect behaviour as the central design principle, we propose a unified framework that bridges chemical ecology and microbial interactions to advance sustainable crop protection. This integrative paradigm offers a scalable roadmap for precision, sustainable, and ecosystem-aligned pest management across diverse agro-ecological systems.

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## Potential of Semiochemicals and Microbials as Sustainable Green Technologies for Managing Pests of Commercial Crops

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Pesticides are used in higher levels both in terms of quantity and frequency that has resulted in tolerance in insect pests in important commercial crops like tobacco and chillies. On chillies around 15 to 25 rounds of pesticides are used in southern states of India to manage black thrips *Thrips parvispinus* that has resulted in accumulation of pesticide residues in the harvested produce which lead to restrictions on the import of chillies and other crops by some western countries. The unregulated tobacco crop (non-FCV) also receives higher quantities of pesticides for the control of lepidopteran and sucking insect pests. Reduction of pesticide-dependence is possible only through adoption of Integrated Pest Management practices especially the use of semiochemicals and microbials as green alternatives which can be used by limiting the quantities or frequency of pesticides used.

Nuclear Polyhedrosis Virus (NPV) is a potent natural microbial ICAR-NIRCA Splt NPV is a biological pesticide produced from entomopathogenic virus particles and it specifically infects and kills the major insect pest tobacco caterpillar *Spodoptera litura* F. The NPV is species specific and one larval equivalent (LE) of *S. litura* contains 1 x 10<sup>9</sup> POBs of the virus. NPV provides control of *Spodoptera litura* within 3 to 4 days after treatment (DAT) by 80-100 % in Gopalapuram area in East Godavari District of Andhra Pradesh during Feb to March 2025. Unlike chemical insecticides, the NPV would not contribute to resistance development in insect pests. Farmers have adopted the technology but the availability and timely supply of the bioagent has become the major limitation.

The entomopathogenic fungi *Beauveria bassiana* and *Metarhizium anisopliae* were found very effective microbials for the management of chilli black thrips *T. parvispinus* in Rajahmundry, Andhra Pradesh during the year 2024 and 2025. The bioagents provided by ICAR-National Bureau of Agriculturally Important Insect Resources (ICAR-NBAIR), viz. *M. anisopliae* and *B. bassiana* controlled the black thrips *T. parvispinus* up to 74.5% and 73.9% respectively at 60 days after planting. At 90 days after planting, application of *M. anisopliae* lead to 90% reduction of thrips population in 7 days after application over control, *B. bassiana* (89%) and both the treatments were all comparable with insecticide imidachloprid (92%). Hence, the microbials offer very effective control of the chilli black thrips on par with insecticides, if they are applied as prescribed and in right method. All the three treatments significantly reduced the black thrip population.

Semiochemicals play an important role through habitat management in a push-pull strategy or through direct application on/in the crop. Green leaf volatile compounds (E)-2-hexenal, (Z)-3-hexenal, (Z)-3-hexenyl acetate, (Z)-3-hexen-1-ol, Linalool proved to be attractive to whitefly *Bemisia tabaci*. Whitefly parasitoid *Encarsia farsosa* is attracted to (Z)-3-hexen-1-ol. Potential repellents for the *B. tabaci* are ocimene, carvacrol, limonene, p-cymene and thymol. Aphids *Myzus nicotianae* reproduce asexually and through parthenogenesis, they can be influenced by other types of volatile compounds that attract their natural enemies. Cinnamyl alcohol, cinnamyl acetate, cinnamaldehyde, germacrene D, B-bourbonene,  $\beta$ -caryophyllene, cinnamyl acetate and benzyl benzoate were reported to be attractive to chilli thrips *F. intonsa*. Methyl isonicotinate, a non-pheromone thrips semiochemical were reported to be attractive to several thrip species. More analytical studies are required to identify the semiochemicals for managing the chilli black thrips *T. parvispinus* and other sucking insect pests of commercial crops.

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## Putting Powdery Mildews' Haustoria under the Magnifying Glass: Exploring the Molecular Warfare Contributing to Pathogenicity and Plant Host Susceptibility during Infection with These Obligate Biotrophic Fungi

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Powdery mildews (PMs) are prevalent diseases of many agricultural crops, including legumes (pulses), cucurbits, cereals. PMs are obligate biotrophic fungal pathogens, relying on haustorial for virulence via delivery of effectors to compromise host immunity, nutrient uptake from the plant host, while these haustoria structures are accommodated in live host epidermal cells benefiting from susceptibility factors relocating to the extrahaustorial membranes to facilitate infection. While many PM effectors have been investigated quite extensively in their role to convey pathogenicity via interaction with host resistance determinants, little is known on the mechanisms regulating effector gene expression in haustoria, or the specific properties of the extrahaustorial membrane to accommodate PM haustoria and host susceptibility.

The presentation will describe; i) a few *Blumeria hordei* effector proteins and their putative mode of action during barley infection. ii) transcriptomics and gene silencing approaches to identify and validate *B. hordei* and *Podosphaera xanthii* transcription factors regulating gene expression in haustoria of cereals' and cucurbits PMs, iii) how proteomics and gene silencing approaches allowed for the identification and validation of barley proteins that are located at the extrahaustorial membrane and that confer full susceptibility to barley powdery mildew. Finally, I will describe a non-GM gene silencing approach, using short oligodeoxynucleotides similar but alternative to RNAi, developed in our lab for functional genomics and how the methodologies could potentially be adapted for crop protection in the field.

We believe that this research will assist traditional breeders and for the designing of CRISPR CAS genome edited powdery mildew resistant crops. Moreover, gene silencing technologies using ectopic oligodeoxynucleotides developed in the lab for functional genomics, are also to be further exploited for environmentally friendly solutions alternative to fungicides, for crop protection in the field.

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## Climate Smart, Safe and Green Fruit Fly Management for Sustainable Horticulture: Case Study in Mango

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Fruit flies (Diptera: Tephritidae) constitute one of the most economically significant insect pest groups affecting horticultural crops across tropical and subtropical regions. Their damage leads to severe direct losses, fruit drop, and quality degradation, often rendering horticultural produce unfit for both domestic markets and export chains. Major pest species (about a dozen) such as *Bactrocera* spp. *Zeugodacus* spp. *Dacus* spp. *Carpomyia* sp. etc., cause substantial economic impact across fruits and vegetables.

Climate change has exacerbated fruit fly incidence by altering temperature, humidity, and rainfall patterns, providing favourable conditions for rapid pest proliferation. High ambient temperatures, increased wind velocity, and erratic spiked rainfall patterns reduce the efficacy of traditional trapping systems and insecticide-based control strategies originally recommended by IIHR (2005). Yield losses in severe infestation scenarios range from 20% to 100%, significantly affecting farmer income and export potential, especially in crops like mango, guava, pomegranate, citrus dragon fruit, cucurbits, and tomato. Here we discuss an updated, green IPM, carried out on *Bactrocera dorsalis* in mango at Bangalore, India

Conventional IPM recommendations—particularly those using outdated wooden-block male annihilation traps with banned insecticides such as dichlorvos or malathion—are no longer effective or compliant with current regulatory restrictions. Moreover, these systems are costly, environmentally damaging, and poorly adopted by farmers due to their low efficiency under changing climate and regulatory conditions. This had highlighted the urgent need for non-insecticidal, climate-resilient, and farmer-friendly and green innovations that can sustainably manage fruit fly populations.

The Rashvee Indigenous Phytosanitary Research System (R-IPRS), funded by BIRAC–DBT support, addressed these challenges through a climate-resilient, liquid lure-based trapping system integrated into a holistic IPM framework. The technology uses specially formulated lures with anti-evaporants and a hooded, rain-guard trap cap that ensures trap performance even under climate changes like high temperatures, rainfall, and strong winds. The system enables the effective reuse of discarded water bottles and overall, reducing costs by up to 70% while contributing to waste recycling and sustainability. It is highly effective for both diversity surveillance and mass trapping of dominant species, thereby supporting data-driven pest forecasting and management decisions.

Complementary components of the R-IPRS package include the Rashvee Herbal Liquid Soap Adjuvant (Veraxaa) for masking fruit volatiles (based on a principle of companion crops in host masking) to prevent female fly landing, and Rashvee Phytofer Protein Bait, which attracts both sexes and is suitable for organic and non-organic farming systems. These tools integrate seamlessly with cultural practices such as sanitation, pit-baiting with fermented fruit (eventually becoming sustainable manures), trunk splashing, and neem-based repellents. For export-oriented crops like mango, the package aligns with post-harvest treatments such as the Hot Water Treatment (48°C for 60 minutes) developed by ICAR-IIHR for achieving zero-infestation and meeting EU standards and high market.

Field validation studies across multiple districts of South Karnataka, including Chikkabalpur, Bengaluru rural, Kolar (Karnataka), demonstrated significant improvements in yield and drastic reductions in fruit infestation when compared to traditional methods. For instance, IPM fields recorded only 2–7% infestation in highly susceptible mango varieties like Totapuri and Neelam, compared to 12–42% under conventional practices. Farmers participating in large-scale validation trials (>600 farmers across South India) reported improved fruit quality, reduced pesticide usage and residue, and enhanced market acceptance.

The technology was validated from ICAR-National Bureau of Agriculturally Insect Resources, University of Agricultural Sciences, Bangalore, and other national institutions, and aligns with GAP and organic certification frameworks. Its adaptability across agro-climatic zones enables effective fruit fly management not only in orchards but also in pack houses, markets, and peri-urban horticultural systems.

Further the Rashvee liquid herbal spray as adjuvant with Azadiractine and bait sprays and baits have proved to be effective against fruit flies not attracted to lures like *Bactrocera minax*, *Dacus ciliatus*, *Carpomyia vesuviana*, *Bactrocera latifrons* etc., Above all the Rashvee lures, herbal liquid soap and bait formulations are available online for pan-India dispatch (+91 63618 25020).

Overall, the R-IPRS system represents a major advancement in climate-smart horticulture by offering an eco-friendly, scalable, and economically viable solution to fruit fly management.

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## **Technology-Enabled Paradigms for Sustainable Insect Pest Management**

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Insect pests, diseases, nematodes, and weeds remain major biotic constraints to global agricultural production, causing up to 40 per cent loss in crop yields annually. Plant diseases alone impose economic losses exceeding USD 220 billion each year, while invasive insect pests contribute at least USD 70 billion to global crop damage. In India, pest-induced yield losses are estimated at INR 1.9–2.25 lakh crore annually, yet substantial scope exists to recover nearly 60 million tonnes of food grains and 65.3 million tonnes of horticultural produce through improved pest management. Such recovery could potentially sustain an additional 300 million people. Despite significant global investment in chemical and biological pest control, crop losses continue to persist, underscoring the need for a new, technology-driven, and ecologically grounded insect pest management paradigm.

Integrated Pest Management (IPM), adopted as India's cardinal crop protection policy in 1985, remains the most viable framework for sustainable pest control. However, its adoption has been constrained by limited stakeholder awareness, inadequate availability of bio-inputs, fragmented implementation, and lack of holistic, location-specific IPM modules. Pest management is inherently a complex, dynamic system involving interactions among crops, pests, natural enemies, climate variability, and human interventions. Consequently, modern IPM must shift from reactive control to predictive, data-driven, and systems-based decision-making.

A contemporary insect pest management paradigm integrates ecological principles with emerging digital, geospatial, and genomic technologies. Central to this framework is an IPM algorithm that includes systematic crop loss assessment, pest risk analysis, real-time surveillance, decision support tools, and harmonized deployment of multiple control tactics. Mechanistic crop-pest simulation models such as InfoCrop enable deeper understanding of pest-induced yield losses by linking pest damage mechanisms with crop physiological processes. These models facilitate development of location-specific economic injury levels and iso-loss curves, enabling need-based, rather than calendar-based, pest control.

Pest surveillance has been transformed through Information and Communication Technology, remote sensing, and geographic information systems. Large scale e-surveillance platforms now support real-time data collection from remote villages, enabling timely advisories to farmers through SMS and digital dashboards. Hyperspectral remote sensing has demonstrated potential in early detection of pest-induced crop stress, particularly in rice brown planthopper infestations. Pest zoning models integrating long-term pest and weather

data with GIS allow identification of regional pest hotspots, guiding strategic crop planning and targeted interventions.

The integration of IPM tactics remains foundational, prioritizing host plant resistance, biological control, cultural practices, behavioural tools, and selective chemical use. Host plant resistance, including Bt cotton and newly released disease-resistant basmati rice varieties, has substantially reduced pesticide dependence. However, emergence of resistant pest biotypes such as pink bollworm in Bt cotton and brown planthopper in rice highlights the need for polygenic resistance breeding and rotational deployment of resistant cultivars.

Cultural and agronomic practices such as crop rotation, intercropping, residue management, optimized sowing dates, balanced fertilization, and regulated irrigation play a crucial role in suppressing pest populations while enhancing ecosystem resilience. Ecological engineering approaches, including flowering bunds, habitat diversification, and conservation of remnant vegetation, strengthen natural enemy populations and reduce reliance on chemicals.

Biological control forms a cornerstone of sustainable pest management through use of predators, parasitoids, and microbial agents such as *Trichoderma*, *Bacillus thuringiensis*, *Beauveria bassiana*, and nucleopolyhedrosis viruses. Classical biological control has successfully managed several invasive pests in India, including papaya mealybug, eucalyptus gall wasp, coconut rugose spiralling whitefly, and cassava mealybug. Scaling up local production of biocontrol agents and promoting rural entrepreneurship are essential for wider adoption.

Behavioural methods using sex pheromones and attract-and-annihilate strategies offer environmentally safe pest suppression, while emerging nanotechnology-based delivery systems promise improved efficiency. Chemical pesticides remain necessary in certain situations but must be applied judiciously based on economic thresholds, seed treatments, and resistance management principles to mitigate the risks of resistance, resurgence, and residues.

Genomic and molecular tools are redefining pest management through DNA barcoding for accurate diagnostics, marker-assisted selection in resistance breeding, RNA interference for targeted gene silencing, and CRISPR-Cas9 gene editing for behavioural or physiological disruption in pests.

Climate change adds further complexity by altering pest distribution, phenology, and crop-pest-natural enemy interactions. Process-based crop-pest models and climate risk tools such as BioSim and CLIMEX are essential for developing climate-resilient IPM strategies. Adaptation requires thermo-tolerant resistant cultivars, resilient biocontrol agents, climate-smart agronomy, and modified pesticide application protocols.

A technology-enabled IPM paradigm integrating ICT, remote sensing, modelling, genomics, ecological engineering, and farmer-centered extension offers a sustainable pathway to reduce crop losses, enhance productivity, protect biodiversity, and improve farmer livelihoods while minimizing environmental degradation.

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## **Insect Pollinators and Their Socio-Economic Importance for Sustainable Agriculture in Bangladesh**

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Agriculture in developing nations is steadily evolving, moving away from conventional cereal cultivation toward the production of high-value cash crops like fruits and vegetables. This transformation presents new challenges in improving and maintaining crop productivity and quality, primarily due to inadequate pollination. Pollination is a vital ecological process that supports food production, biodiversity, and ecosystem stability. It involves the transfer of pollen from the male to the female parts of flowers, facilitating plant reproduction. Approximately 75% of cultivated crops depend on animal pollination, underscoring its importance in producing fruits, vegetables, fibers, and medicinal plants. Insect pollinators, in particular, play a central role in global food production, with over 80% of flowering plants relying on them for reproduction. Out of about 100 crop species that provide 90% of the world's food supply, 71 are pollinated by bees, while others depend on butterflies, moths, thrips, and wasps. In developing countries like Bangladesh, where agriculture is the cornerstone of the national economy, insect pollinators are indispensable for ensuring food security and sustaining the livelihoods of millions of smallholder farmers. Managed honeybees (*Apis mellifera* and *A. cerana*) serve as the primary pollinators, while wild bees, bumblebees, solitary bees, butterflies, moths, flies, beetles, and wasps play complementary roles. Important crops such as mustard, onion, melon, cucumber, tomato, mango, litchi, and papaya depend heavily on these pollinators for high yield and quality. The diversity of pollinators ensures the stability of agricultural systems and enhances resilience to environmental stresses.

Pollinators are also essential for maintaining biodiversity and ecosystem health. By enabling plant reproduction, they sustain wild flora, promote genetic diversity, and uphold ecosystem balance. Beyond pollination, these species contribute to rural economies through valuable products such as honey, beeswax, royal jelly, propolis, and pollen, which enhance nutrition and generate income.

However, pollinator populations are rapidly declining due to habitat destruction, pesticide misuse, monoculture, deforestation, pollution, and climate change. This decline threatens crop yields, biodiversity, and food security. Therefore, developing nations must adopt conservation strategies such as habitat restoration, integrated pest management, flower-rich landscapes, and public awareness programs. Conserving insect pollinators is crucial for sustaining agricultural productivity, ecological balance, and socio-economic development in Bangladesh and other developing countries.

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## **Pesticide-Mediated Disruption of Pollination Services: Lessons From Mustard Agroecosystems and Implications for Global Honey Trade**

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Mustard-based agroecosystems rely heavily on pollinator-mediated reproduction for optimal seed set and yield, while also supporting large-scale honey production and rural apicultural livelihoods. However, the intensive and often prophylactic use of synthetic pesticides threatens this delicate ecological interdependence. Pesticides applied to soil and foliage are absorbed through roots and leaves and subsequently translocated via vascular pathways to developing floral organs. Within reproductive tissues, these agrochemicals induce oxidative stress, disrupt nutrient balance and hormonal regulation, and interfere with normal pollen development, resulting in reduced pollen viability, impaired germination, altered exine morphology, and compromised floral signalling—ultimately diminishing pollination efficiency. Pesticide residues in nectar and pollen reduce floral attractiveness and cause sublethal stress in bees, affecting behaviour, immunity, and colony health.

The problem extends beyond the field. When bees collect contaminated nectar, pesticide residues enter the hive and may accumulate in honey and other hive products. If residue levels exceed permissible limits, honey may face market rejection or export bans. Thus, pesticide overuse creates a chain reaction—from soil uptake and systemic plant stress to pollinator exposure and economic losses in the global honey trade. To mechanistically investigate early stress initiation at the root level, we employed a phytofluidics-based microfluidic device to simulate controlled agrochemical exposure in mustard roots with real-time monitoring. In parallel, non-invasive Raman spectroscopy was used to detect in situ biochemical alterations associated with pesticide-induced stress. Integrating plant physiology, pollinator ecology, and trade perspectives, we emphasize the urgent need for Integrated Pest Management (IPM), pollinator-sensitive application protocols, biopesticides, habitat diversification, and systematic residue monitoring in floral and hive matrices. A systems-level sustainability framework—supported by innovative experimental technologies—is essential to ensure that crop protection does not come at the cost of pollination resilience, honey integrity, and long-term farmer–beekeeper livelihoods.

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## Intercrop-Mediated Resource Enhancement for Honeybees in Lac Integrated Farming Systems (LIFS)

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Lac cultivation (*Kerria lacca*) and apiculture represent important income sources for smallholder farmers, yet their integration remains poorly understood. This study investigated whether strategic intercropping in lac-apiculture systems could enhance pollinator resource availability and colony performance while utilizing honeybee-mediated honeydew harvesting. A split-plot randomized complete block design was implemented with five intercrop types (strawberry, coriander, mustard, sweet corn, and control) as main plots and three bee treatments (*Apis cerana*, *A. mellifera*, and no bees) as subplots across 45 plots over 180 days. We quantified honeydew foraging behaviour, floral visitation patterns, pollen diversity, colony performance metrics, honey production and quality, pollination services, and intercrop yields. Both *Apis cerana* and *Apis mellifera* species foraged on lac insect honeydew, demonstrating facultative honeydew harvesting behaviour, with *Apis cerana* demonstrating higher activity. Pollen analysis revealed diverse resource utilization, with 35-65% of pollen loads derived from intercrops and the remainder from wild sources, indicating landscape-level foraging. Honey electrical conductivity measurement indicated marginal honeydew incorporation, producing honeydew-floral blend honey. *A. cerana* colonies produced significantly more honey ( $2.65 \pm 0.15$  kg/colony) than *A. mellifera* ( $1.84 \pm 0.11$  kg/colony;  $p < 0.05$ ). Bee presence enhanced strawberry fruit set from 54.4% (bagged) to 95.9% (open pollination). Intercrop yields increased 12-70% with bee presence, with strawberry showing the greatest response to bee pollination. Strategic intercropping in integrated apiculture-lac systems creates synergistic benefits through dual resource provision (honeydew + floral resources), enhanced pollination services, and diversified income streams. *A. cerana* demonstrated superior performance in honey production and pollination services. This integration represents a novel agroecological approach to sustainable secondary agriculture intensification.

**ILT - 14**

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## **Digital Solutions and Outreach in Agriculture**

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The global agricultural sector faces unprecedented challenges, including the need to feed an estimated 9 billion people by 2050 amidst climate volatility, resource scarcity, and labor shortages. This presentation outlines why digital transformation is no longer optional but is the essential foundation for modern, sustainable food systems. By leveraging Precision Agriculture, farmers can utilize Variable Rate Technology (VRT) and GPS guidance to ensure crops receive exact inputs, potentially reducing waste by 20% and increasing yields by up to 15%. Furthermore, the integration of AI and Predictive Analytics shifts data from simple observation to "Decision-Grade Intelligence," offering personalized agronomic advice, pest prediction, and real-time market pricing. A critical component of this evolution is Digital Outreach—the "nervous system" of modern farming. Moving from traditional "physical" models to "digital-first" strategies allows a single platform to reach millions instantly through social media, agro-influencers, and mobile-first tools like the Bayer FarmRise App. Despite significant hurdles—such as high initial costs, connectivity gaps in rural areas, and the need for improved digital literacy—the way forward requires a commitment to interoperable systems and farmer training. Ultimately, the goal is a connected ecosystem where biology meets big data, ensuring every farmer has access to the knowledge and financial security necessary to thrive in a changing world

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## **Image-Based Plant Disease Detection and Severity Estimation Using Deep Learning Techniques**

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Plant diseases remain one of the most serious challenges in modern agriculture, directly affecting crop yield, food security, and farmer livelihoods. Traditionally, disease identification and severity estimation have relied heavily on manual inspection by plant pathologists. Although expert observation is valuable, it is often time-consuming, subjective, and difficult to scale for large agricultural fields. In this context, image-based plant disease analysis has emerged as a powerful and practical solution for early detection and accurate severity grading.

With the rapid development of computer vision, artificial intelligence, and deep learning, automated disease diagnosis systems are becoming increasingly reliable. These technologies allow farmers and researchers to detect symptoms directly from leaf images, estimate the infected area, and even predict disease progression. Such systems not only support timely intervention but also help reduce unnecessary pesticide use by applying treatments based on disease intensity rather than guesswork. Image-based plant disease analysis generally follows a structured pipeline. First, leaf images are captured using digital cameras or smartphones under controlled or field conditions. The captured images are then processed to improve quality and remove noise. After pre-processing, the infected regions are segmented using methods such as thresholding or clustering techniques. The percentage of affected area is computed and based on affected area disease intensity is calculated.

In recent years, deep learning models; especially Convolutional Neural Networks (CNNs) have transformed plant disease diagnosis. CNNs automatically learn complex patterns such as texture changes, lesion shapes, and discoloration directly from training images, eliminating the need for manual feature extraction. Advanced architectures such as Inception-V3 and transfer learning models have been successfully applied to classify plant diseases and predict severity levels with strong performance. These models can categorize leaves into multiple severity grades (healthy, mild, moderate, and severe), providing decision support tools for precision agriculture. The proposed approach enables classification of plant leaves into multiple severity categories (healthy, mild, moderate, severe), including healthy, mild, moderate, and severe infection stages. Image-based disease severity assessment systems demonstrate strong potential across various crops, including potato, wheat, banana, pomegranate, chili, and sugarcane. The integration of deep learning with image-based analysis provides an effective decision-support tool for precision agriculture, facilitating early disease detection, optimized pesticide application, and sustainable crop management.

**ILT - 16**

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**Convergence for Resilience: Integrating Chemistry, Biology, and Digital Intelligence for Climate-Smart Sustainable Agriculture**

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The global agriculture sector stands at a critical inflection point. By 2050, we must produce 50% more food for a projected population of 10 billion people, yet we face unprecedented challenges: climate change intensifying abiotic stress, declining cropland per capita (from 0.45 to 0.21 hectares), increasing pest resistance, and the imperative to reduce environmental impact. Traditional approaches - whether purely chemical or purely biological - are insufficient to meet this challenge. The path forward requires convergence: the strategic integration of advanced chemistry, cutting-edge biology, and intelligent digital technologies.

This keynote presents a holistic framework for sustainable agriculture that transcends the false dichotomy between conventional and biological crop protection. Drawing on PI Industries' experience as India's innovation engine in agrochemical and biological solutions, we demonstrate how the synergistic application of synthetic chemistry, biological control agents, biostimulants, and AI-powered precision agriculture can deliver superior outcomes across three critical dimensions: productivity, profitability, and planetary health.

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## **Vision-based Detection of Crop Diseases and Pests using Deep Learning Techniques**

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In India, Agriculture plays a significant role in shaping the country's economy, ensuring food security and sustaining livelihoods. However, crop production is severely affected by diseases and insect-pests' infestations, leading to reduced crop yield and posing a threat to food security. Conventional approaches of disease and pest identification rely primarily on manual field inspection & expert knowledge, which are labor-intensive, time consuming and impractical for large-scale deployment. In this context, diagnosis of diseases and insect-pests using latest Artificial Intelligence techniques would be a viable and scalable solution towards the farming community.

Recently, the advancements in Artificial Intelligence (AI) have significantly transformed the agriculture sector by provided automated and data-driven alternatives to conventional methods crop health monitoring. Among these, Deep learning (DL) techniques, particularly the convolutional neural networks (CNNs), have emerged as a powerful tool for crop disease and insect-pests detection through analysing large number of image dataset. CNNs represent an advanced version of feed-forward neural network architecture, primarily designed for supervised vision-based classification tasks. The hierarchical layered structure of CNNs enable automatic extraction of localized features such as lesion shapes, texture variations, discoloration patterns, directly from raw images, eliminating the need for handcrafted feature engineering. Building upon the foundational architecture of LeNet-5, modern CNN models such as InceptionNet, ResNet, MobileNet, and EfficientNet have shown significantly improved predictive performance in crop disease and pests' classification tasks. These architectures incorporate innovations such as residual connections, depth-wise separable convolutions, and multi-scale feature extraction, allowing deeper networks with enhanced generalization capability and computational efficiency. Similarly, transformer-based architectures, originally developed for natural language processing (NLP), have recently emerged as an alternative paradigm for the vision-oriented diagnostic tasks. The adaptation of Transformer networks into computer vision has led to emergence of Vision Transformer (ViT) networks, which capture the global contextual information and long-range relationships within the images. Unlike the CNNs, which rely on convolutional kernels to capture local spatial patterns, ViT network segments the whole image into small patches and process them as sequence of tokens to identifying the inherent complex patterns lying within the image features. Through self-attention mechanisms, ViTs learn complex feature

interactions across the entire image, enabling more comprehensive representation learning, particularly in scenarios involving subtle and spatially distributed disease symptoms. Meanwhile, beyond classification tasks, recent deep learning approaches have also been extended to object detection, facilitating not only the recognition of disease or pest categories but also the precise localization of affected regions within images. In this respect, the YOLO (You Only Look Once) family of models has gained considerable attention due to its accuracy and efficiency in real-time object detection tasks. YOLO introduced a unified detection framework that predicts object categories and their spatial locations in a single forward pass of the network. Its grid-based design strategy allows simultaneous prediction of bounding boxes and corresponding class probabilities, making it particularly suitable for rapid and precise insect pest detection under field conditions.

Since 2021, we, at ICAR-IASRI, are involved in extensive research focused on developing deep learning-based frameworks for crop diseases and pests' detection. As a part of this research, a large and diverse image dataset has been systematically collected and curated under natural field conditions from multiple agro-climatic regions of the country. The dataset encompasses various crops, covering numerous disease categories as well as insect pests and their associated symptoms, thereby ensuring variability in background complexity, growth stages, and severity levels. The collected images were carefully pre-processed annotated, and organized to facilitate for training and evaluation of several deep learning architectures including ResNet, EfficientNet, MobileNet, Vision Transformers, YOLO-based models, etc. In this respect, crop disease identification was primarily addressed as an image classification problem, employing convolutional neural network (CNN)-based and transformer-based architectures to learn discriminative visual features directly from field images. In contrast, insect-pest and their symptoms detection were formulated as object detection tasks, utilizing the YOLO-based models to simultaneously identify pest categories and localize the affected regions within the images. Collectively, implementation of CNNs, Vision Transformers, and YOLO-based models in crop diseases and pests' detection, enabling sustainable and technology-driven crop protection strategies.

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## Leveraging Nematode-Based Soil Health Indicators for Sustainable Crop Production

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Soil health, basic to agricultural productivity, encompasses the physical, chemical, and biological properties that support plant growth, nutrient cycling, and ecosystem resilience. Nematodes and microbial communities play a crucial role in regulating soil fertility and ecosystem function. Nematodes occupy diverse trophic positions, including bacterivores, fungivores, omnivores, predators, and plant-parasitic species. Soil microbes including bacteria, fungi, actinomycetes, protozoa, turbellarians, enchytraeids, collembolans, tardigrades etc. mediate decomposition, consumption, nutrient mineralization, and symbiotic interactions. The activity of these organisms creates a living continuum in which the performance of crops, soil fertility, and ecosystem stability are interlinked. Microbivorous nematodes facilitate nutrient cycling by accelerating nitrogen, phosphorus, and carbon turnover. Plant-parasitic nematodes (PPNs) impose direct stress on crops, reducing yield and quality. Soil microbial communities influence the same processes through organic matter decomposition, symbiosis, and metabolite production. Nematode-based indices, including the Maturity Index (MI), Enrichment Index (EI), Structure Index (SI), Shannon Diversity Index (SDI), and Nematode Channel Ratio (NCR), quantify soil biological status and ecological stability. These indices serve as early indicators of fertility changes prior to visible symptoms. Diverse agroecological zones exhibit considerable variability in soil biota. Correlations exist between soil physicochemical properties, microbial diversity, nematode community composition, and crop outcomes. Such relationships emphasize the importance of site-specific soil health monitoring to optimize productivity sustainably.

Recent advances in biotechnology provide powerful tools to investigate and manipulate the soil continuum. Metagenomics and meta-transcriptomics allow comprehensive profiling of microbial and nematode communities, including non-culturable taxa, while CRISPR-mediated functional genomics facilitates the identification of nematode effectors and microbial genes essential for nutrient cycling and biocontrol. Biofertilizer and microbial consortia enhance soil fertility and crop resilience, promoting sustainable agricultural intensification.

Artificial intelligence (AI) can complement these approaches by enabling predictive modelling and decision support systems. Machine learning algorithms can relate soil biota composition, trophic indices, and physicochemical parameters to crop yield. Deep learning frameworks may integrate multi-omic, climatic, and spatial data to simulate soil-plant-

microbe interactions. Integrating AI-based digital twins with remote sensing can permit monitoring of soil health, nematode risk, and microbial activity at regional scales, providing insights for farmers and policymakers for selection of possible measures.

Philosophically, the soil biota continuum resonates with the concepts of *Prakriti* (nature), *Atma* (soul / energy) and interdependence, where each organism contributes to the collective vitality of the ecosystem. The unseen processes of microbes and nematodes underlie visible productivity, echoing the principle that subtle forces sustain multiple outcomes. Understanding and managing this continuum through modern biotechnology and AI, therefore, represents both a scientific and ethical effort towards sustainable and resilient agriculture.

Combining nematode and microbial ecology with biotechnological and AI tools provides a comprehensive framework to monitor, predict, and enhance soil health and crop productivity. This approach supports sustainable management of agroecosystems, aligns with ecological and philosophical perspectives on interdependence, and addresses critical challenges in food security and climate resilience.

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## Promising Green Alternatives to Sustainable Nematode Management in Horticultural Crops

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Much of the research on nematode management is focused on horticultural crops in view of their profitability. However, horticultural crops also provide ideal ecosystems for proliferation of parasitic nematodes. Among them, root-knot nematodes (*Meloidogyne* spp.), reniform nematode (*Rotylenchulus reniformis*) and burrowing nematode (*Radopholus similis*) are the major pests.

In view of the growing awareness about the harmful impact of chemical pesticides and demand for organic produce, more and more horticulture farmers are opting for green alternatives for pest and disease management, including nematodes. These technologies focus mainly on biological, physical, and cultural mechanisms that suppress nematode populations while maintaining soil health.

The following technologies offer cheap green solutions.

**Nursery management:** Fruit nurseries (tissue culture plants, clones, grafts etc.) are often raised initially in soilless media, but are transferred for hardening to soil obtained from established orchards that is often infested with nematodes. The nematode infected planting material goes unnoticed and transported far and wide, thus disseminating nematodes to new loci permanently. Raising planting materials for hardening in nematode-free soil alleviates the problem. Using solarised soil for hardening is an easy and practicable method for raising nematode-free planting material.

**Soil solarization:** Deep soil ploughing during summer months 2-3 times at 10-15 days' interval during field preparation kills most of the nematodes due to starvation, desiccation and exposure to high temperatures. In protected cultivation systems in plains, during May/June, level the soil in polyhouse, give light irrigation and cover the soil surface with 25 µm transparent polythene sheet and seal them. Close the polyhouse for about 4 to 5 weeks. The temperature in the immediate subsurface raises to as high as 62° C, high enough to kill majority of the nematodes in the rhizospheric zone.

**Organic amendments:** Addition of organic materials in the form of FYM, deoiled cakes of plants like neem, castor, pongamia etc. about 2 weeks prior to planting is highly beneficial. This practice provides additional benefits like improving the nutrient status of the soil, imparting tolerance of the crop to nematode infestation, promoting bioagents, besides declining nematode populations significantly.

**Bioagents:** Nematode egg parasitic fungi like, *Purpureocillium lilacinum*, *Pochonia chlamydosporia* are very popular and easily available, though quality control remains an issue. Other fungal bioagents like *Trichoderma* spp. induce systemic resistance and are widely used. Rhizobacteria like *Bacillus subtilis* and *Pseudomonas fluorescens* produce toxins deleterious to nematodes.

**Botanical nematicides and Biofumigation:** Biofumigation involves growing and then "plowing in" brassicaceous plants (like mustard). When crushed, these plants release isothiocyanates, natural gases that act as organic fumigants. Botanical extracts of plants like neem (*Azadirachta indica*) contains azadirachtin, which disrupts nematode feeding and reproduction. Other effective extracts include those from Marigolds (*Tagetes*), which release alpha-terthienyl, a potent nematicide. Incorporating fresh organic matter like Crotalaria (sunn hemp) or sorghum (green manuring) into the soil releases organic acids and ammonia during decomposition, which are lethal to many nematode species.

**Green molecular tools:** RNA Interference (RNAi) is cutting-edge technology where plants are engineered to produce double-stranded RNA (dsRNA). When the nematode feeds on the plant, this RNA silences essential genes within the nematode, preventing it from maturing or reproducing. Using biodegradable nanoparticles to deliver botanical oils or BCAs directly to the root zone, reduces the amount of material needed and preventing runoff.

**Green chemical nematicides:** In the last decade or so a new class of chemicals nematicides has been launched having entirely different chemistry and modes of action. These molecules are much safe to the environment and non-target organisms. These include (i) Fluopyram (Velum Prime®/Verango® belonging to class Pyridinyl enthylbenzamide, with SDHI Complex II mode of action); (ii) Fluensulfone (Nimitz® belonging to class Fluoroalkenyle), and Fluazaindolizine (Selibro®/Reklemel® belonging to class Sulfonamide nematicide). Yet another new molecule Vaniva (Cyclobutrifluram has been launched recently in India.

**Futuristic new technologies:** Virtual screening techniques like molecular docking may impact the identification of promising novel nematicidal molecules. Engineering resistance against nematodes using Arabidopsis by knocking out parasitism elicit factors using CRISPR/Cas9 technology appears promising.

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## **Are Alien Invasive Insects A Threat to Indian Agriculture**

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Alien invasive species are species that are not native to a specific location but have a tendency to spread to a degree which can cause damage to the environment, human economy or human health. The major drivers of invasive species introductions appear to be trade and travel. The globalization of trade and transport has further accelerated their spread both in intentional and unintentional ways. During the past decade more than a dozen alien invasive species have been reported to have invaded the geographical boundaries of India. India being one among the 12 megadiversity countries in the world with varied agroclimatic zones provide congenial conditions for the invading alien species to establish. Countries with diverse commodities and/or large trade volumes are likely to be the greatest source of invasive pests and pathogens, whereas countries with developing economies most likely play a lesser role as sources of invasion. Invasive pest species pose a serious threat to native biodiversity and after becoming locally dominant invade natural communities. The Convention on Biological Diversity identified "Invasive Alien Species" (IAS) as a major factor in the loss of biodiversity based on their capacity to outcompete or prey on native species and subsequently cause a degradation of the biodiversity in the area of their introduction. Alien species have been recognized as one of the greatest and most rapidly growing threat to agricultural biodiversity, forestry, human and animal health, etc. resulting in huge economic losses. Invasive species present significant threats to global agriculture, although how the magnitude and distribution of the threats vary between countries and regions remains unclear. These species, if not accompanied by the natural enemies which keep them in check in their native range, can multiply in large proportion and cause damage to economically important plant species and crops. Some invasive species are serious polyphagous voracious pests with a wide host range of plant species. Spread of an Invasive Alien Species often impacts the ecological and economic well-being of a country. They can transform the structure and species composition of an ecosystem by out competing native species for resources or indirectly by changing the way nutrients are cycled through the system thereby effecting agricultural yield. The impact of introduction of new pest species in a new area can only be minimized by the basic knowledge of invasive pest species with international cooperation through exchange of information on invasive pests and their natural enemies. The most effective way to stop the negative impacts of IAS is through prevent their spread by regulating the trade or movement of a species and once an IAS has arrived, early detection, monitoring and eradication can stop it from spreading. There is an urgent need for assessment of associated ecological problems in different ecosystems, economic damage and methods of management through interdisciplinary research.

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## Climate Change Induced Changes in Pathogen Dynamics of Major Crops in Eastern India

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The state of West Bengal is characterized by pronounced agro-ecological heterogeneity, encompassing the Himalayan foothills of the Terai and Dooars, the intensively cultivated Gangetic alluvial plains, the drought-prone red and lateritic tracts of western districts, and the fragile coastal and deltaic ecosystems of the Sundarbans. While this diversity underpins high agricultural and horticultural productivity, it also increases vulnerability to climate variability and long-term climate change. Rice-based cropping systems dominate agriculture in West Bengal and are particularly sensitive to these climatic perturbations. Delayed monsoon onset, mid-season dry spells and terminal drought adversely affect transplanting, tillering and grain filling in Aman rice, whereas floods and water logging damage standing crops in low-lying areas. Plant disease dynamics have also shifted substantially. High humidity, prolonged leaf wetness, frequent rainfall events and elevated temperatures favour fungal and bacterial diseases. Parallel assessments of rice pathology highlight that diseases such as false smut and sheath rot are now becoming major threats, while panicle blight and grain discoloration are emerging concerns that compromised yield and seed quality. Likewise, *Choanephora cucurbitarum* has become a major biotic constraint in vegetables and other crops during Kharif season, and *Sclerotinia sclerotiorum*, first detected in West Bengal in 1988, has now expanded to over 25 host species, underscoring its adaptive potential under changing climates. These findings reinforce that climate-induced shifts are accelerating pathogen evolution, expanding host ranges, and transforming minor pests into major constraints.

Rice, vegetable, and potato-based cropping systems dominate the agricultural crop production systems of West Bengal, where pest and pathogen pressures are increasingly tuned by climatic variability. Long-term surveillance and predictive modeling is essential for assessing pathogen dynamics as well as guiding policy and framing sustainable management strategies. A decade-long (2011–2021) real-time monitoring of tomato diseases in the Gangetic alluvial region revealed that target leaf spot and tomato leaf curl were the two most prevalent threats during the Rabi season, while tomato leaf curl, early blight, and late blight predominated in the summer season. Weather-driven risk factors for *Corynespora cassiicola* were identified, and region-specific forewarning models were developed using multiple regression, multinomial logistic regression, support vector machines, and one-dimensional convolutional neural networks. Notably, climate model-based projections (PRECIS, 1991–2050) suggest a rising trend in target leaf spot severity, particularly during 2031–2040 and

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Agricultural and Ecological Research Unit, Indian Statistical Institute, Kolkata, India*

2041–2050 decadal periods. To safeguard crop productivity, near real-time disease surveillance, integration of advanced diagnostic tools (including image-based systems), and predictive modeling must be embedded within regional pest management frameworks. Such approaches will be pivotal in mitigating future disease outbreaks and ensuring resilient and sustainable food production systems.

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## Control of Tea Pathogens by Rhizosphere Modification

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The majority of tea infections are caused by phytopathogenic fungi, bacteria, and algae, each with a specific set of symptoms. Three such fungal species were collected from the infected tea leaves in the experimental garden of CO-FAM, University of North Bengal. These species included *Fusarium proliferatum* strain TP1 (NCBI GenBank accession: OR101701.1), *Fusarium fujikuroi* isolate TP2 (NCBI GenBank accession: OR426452.1), *Pilatorporus ostreiformis* isolate TP3 (NCBI GenBank accession: OR101854.1). Koch's postulate established the pathogenic nature of these fungi. Subsequently twelve different bacteria were isolated from 12 month old plants and based on N, P, and K solubilisation, phytohormone production, biofilm production, fungal wall degradation and also VOC production, six different bacteria were screened, they included TR01K: *Bacillus vallismortis* strain TR01K (NCBI acc: number MT672714), BT: *Bacillus luti* strain DBBA\_BT1 (NCBI acc: MZ229975), BM: *Bacillus wiedmannii* bv. *thuringiensis* strain BDBA\_BM1 (NCBI acc: MZ229894), BS: *Bacillus paramycoides* strain BDBA\_SXCM4 (NCBI acc: MW917244), PSB: *Bacillus paramycoides* strain DBBA\_P1 (NCBI acc: MZ227489), KSB: *Bacillus paramycoides* strain DBBA\_K1 (NCBI acc: MZ227495). They not only inhibited the aforesaid fungi but also produced different low molecular weight compounds like Rhizotocins, Fusaracidin A, Zwittermicin A, Pentacosane, Subtulene A, Surfactin homologues, Pyripyropene A (PP-A), Thuringiensin, pyrrole-2-carboxylic acid, all of which contributes in mitigating major biotic stresses along with improving plant growth to a considerable extent.

**ILT - 23**

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## **The Illusion of Intelligence: Security Risks in Modern AI Systems**

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Artificial intelligence (AI) is now embedded in many everyday systems, from voice assistants and recommendation engines to medical diagnostics and autonomous vehicles. As AI becomes more capable and widely deployed, questions about its reliability and security become increasingly important. In this talk, we will explore two key security threats: (i) adversarial attacks, where small and often unnoticed changes to input data can cause an AI system to produce incorrect results, and (ii) backdoor attacks, where hidden changes made during system development allow the AI to behave normally in most situations but respond incorrectly when exposed to a specific hidden pattern. We will also examine how these attacks work and why they pose practical risks. Finally, we will discuss measures that can strengthen AI reliability and trust. These concerns are becoming increasingly relevant as AI systems are adopted across the agricultural sector.

**ILT - 24**

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## **Pest Management in Crops: Pesticides, Conventional Alternatives, and Effects on Ecological Functions**

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Agricultural intensification wiped out natural and seminatural areas, increased pesticide consumption, and led to increased frequency of pests. Between 2000 and 2020, over 30% increase in the pesticide was reported in the world. While the old-generation pesticide has been replaced by the new-generation pesticides, the pattern is different between regions of the world. What impact they have on pests, beneficial insects and yield needs thorough critical investigation. The conventional alternatives of pesticide application are the adoption of mechanical, physical, biological and cultural alternatives. The effects of pesticides on ecological functioning in crop systems is a worrisome fact. In my talk, I will be talking about the pest management practices in tea in north-eastern India and in agricultural crops in India.

OP - 1

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## **Interactions among Pollination, Irrigation, and Fertilizer Inputs Shape Yield and Seed Nutrients in Mustard**

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Crop productivity is collectively enhanced by pollination, water availability, and nutrient inputs; however, the lack of comprehensive knowledge regarding the interactions between pollination and soil-water management hinders the optimization of agricultural practices for enhanced crop productivity. To address this, we conducted a full-factorial field experiment using two levels of each factor, including pollination (open vs. closed), fertilization (standard vs. absent), and irrigation (standard vs. reduced), on mustard in the district of Alipurduar, West Bengal. Open pollination significantly improved pod and seed traits and enhanced nutritional parameters, including sugar and starch content. Fertilization increased all measured yield traits and one nutritional component (starch) and reduced lipid, although its interaction with pollination generally led to reduced performance relative to expected additive outcomes, except in starch content, where a synergistic effect emerged. Irrigation effects varied, positively influencing pod length and seed weight. Interactive effects between pollination and irrigation were predominantly negative. The combined effects of irrigation, fertilization, and pollination were not always additive; instead, they produced complex trade-offs, sometimes amplifying and sometimes diminishing the benefits of pollination. These strong interaction effects underscore the fragile balance between ecological services and agricultural inputs. Overall, the findings reveal that yield and nutritional quality are strongly constrained by pollination limitation and are regulated by complex ecological-agronomic interactions, underscoring the need for integrated management strategies to improve crop productivity.

OP – 2

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## **Soil Blueprint: Edaphic Drivers of Nesting Success in Soil Nesting Solitary Bees Across Agro-Ecosystems of Southern West Bengal, India**

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The influence of edaphic properties, from physical texture to chemical composition, on the nesting success of solitary soil nesting solitary bees (SNSB) is critical but under-

explored. Changes in nesting density may affect pollination services, limiting sustainable agriculture. This two-year study in India investigated SNSB microhabitat preferences across two agro-climatic zones: Gangetic alluvial and mangrove-surrounded Coastal saline, under varying agricultural intensification. A total of 114 nests under Apidae, Halictidae, and Colletidae families were documented. Predictor variables such as soil physical (n=4) and chemical (n=7) properties, bare soil, vegetation cover, tillage and pesticide history were assessed. Nesting density was positively associated with temperature, pesticide-free duration and nitrogen but negatively associated with potassium, humidity, bulk density and sand content. Sandy clay loam soil favoured nesting. Available P<sub>2</sub>O<sub>5</sub> showed a curvilinear effect, while high electrical conductivity reduced nesting, indicating salinity stress. These findings highlight a foundation for pollinator friendly practices and future SNSB conservation research in agro- ecosystems.

OP – 3

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## **A Hope for Revival: Environmental Remediation Augments Population Resilience and Physiological Recovery in the Native Asian Honeybee (*Apis cerana*) within Intensive Agroecosystems**

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Global pollinator decline poses a critical threat to food security, with pesticide exposure recognized as a primary driver of honeybee population losses. This study evaluated the capacity for demographic and physiological recovery of the native Asian honeybee (*Apis cerana*) following chronic pesticide stress under contrasting agricultural intensities. Experimental colonies were established in high-intensity cropping (HIC) and low-intensity cropping (LIC) systems and subsequently reciprocally translocated to assess recovery dynamics. Colony performance indicators—including adult population size, brood (larval and pupal) abundance, and growth trends—were monitored alongside molecular biomarkers associated with oxidative stress and apoptosis. Colonies transferred from LIC to HIC exhibited significant declines in adult and brood populations, confirming the detrimental effects of intensive agrochemical exposure. In contrast, colonies relocated from HIC to LIC demonstrated marked demographic recovery. At the molecular level, remediation was characterized by normalization of reactive oxygen species (ROS) activity and significant downregulation of mitochondrial- and endoplasmic reticulum-mediated apoptotic pathways. These findings provide compelling field-based evidence that *Apis cerana* populations possess substantial resilience and can recover physiologically and demographically once pesticide pressure is removed. The study underscores the critical role of agroecological remediation and reduced chemical inputs in restoring pollinator health and strengthening sustainable agricultural systems.

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## **Bugs, Brinjal and Buffers: How Landscape Features and Farm Management Influence Arthropod Pests and their Natural Enemies**

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Agricultural intensification has altered landscape structure and farm management practices, often weakening ecological processes that regulate crop pests. We present findings from a multi-scale study conducted across 49 brinjal (*Solanum melongena*) farms in West Bengal, India, examining how landscape heterogeneity and local management influence natural enemies, pest populations, predation pressure, and crop damage. Landscape composition and configuration were quantified using GIS and remote sensing at four spatial scales (200 m, 500 m, 1000 m, and 2000 m), while farm-level variables included pesticide intensity, tillage frequency, weed cover, and weed diversity. Arthropods were sampled using vacuum, pan, pitfall, sticky, and pheromone traps, and predation was assessed using plasticine sentinel prey. Pest damage was evaluated through standardized measurements of leaf, flower, and fruit injury. Data were analyzed using generalized linear mixed models. Across 29 farms, more than 28,500 pest individuals were recorded. Predation rates ranged from 18.8% to 66.7% (mean =  $33.4 \pm 11.2\%$ ). Spider abundance was strongly associated with landscape complexity and diversity ( $R^2 = 0.75$ ), increasing with area-weighted mean shape index at 2 km ( $p = 0.01$ ) and Shannon diversity at 1 km ( $p = 0.019$ ), but declining with pesticide intensity ( $p = 0.007$ ). Coccinellid abundance increased with vegetation cover at 200 m ( $\beta = 0.038$ ,  $p = 0.039$ ) and declined with patch complexity ( $\beta = -1.46$ ,  $p = 0.002$ ). Parasitic Hymenoptera richness decreased with edge density at 2 km ( $\beta = -0.0011$ ,  $p = 0.041$ ). Pest responses were also scale dependent. Brinjal shoot and fruit borer abundance increased with landscape diversity at 200 m ( $\beta = 1.66$ ,  $p = 0.004$ ), while aphid and leafhopper abundance was negatively associated with edge density at 2 km ( $p < 0.01$ ). Mean crop damage reached 24% for fruits, 35% for leaves, and 40% for flowers, with substantial spatial variation. Higher semi-natural habitat covers at 500 m–1000 m reduced leaf and fruit damage, while pesticide use showed limited effectiveness in suppressing pests. These results demonstrate that landscape heterogeneity enhances biological control primarily at broader spatial scales, whereas intensive chemical management undermines beneficial arthropods without consistent pest suppression. Integrating landscape-level planning with ecologically informed farm management is therefore essential for sustainable pest regulation.

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## **A 60 Ghz Antenna and Machine Learning Based System for Smart Agricultural Monitoring**

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This work presents a novel integrated framework that combines 60 GHz antenna technology with machine learning (ML) models for advanced agricultural monitoring and prediction. The selection of 60 GHz sensing is motivated by its demonstrated capabilities in biomedical and medical sensing—such as high-resolution detection of subtle physiological movements, tissue-penetrative and non-invasive subsurface sensing, non-contact and hygienic operation, real-time continuous monitoring, and compact, integral form factors. Leveraging these proven sensing attributes, the proposed system applies 60 GHz antennas to agricultural environments to acquire rich, real-time data. These data are processed using supervised ML techniques, including convolutional neural networks (CNNs) for image-based stress detection and recurrent neural networks (RNNs) for temporal growth analysis, to develop predictive models for crop health and yield estimation. The synergistic integration of high-frequency radio frequency sensing and ML enables early and precise identification of biotic and abiotic stresses, reliable crop production forecasting, and data-driven resource management. Overall, the framework highlights the potential of translating sensing strengths evidenced in biomedical contexts into agriculture, thereby promoting sustainability, optimizing productivity, and supporting precision farming.

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## Development of an Optimized Nitrogen-Amended Sorghum Substrate for Large-Scale Multiplication of *Trichoderma* *harzianum*

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*Trichoderma* spp. is a genus of free living, asexually reproducing, green spored ascomycetes fungi that are found in root and soil ecosystem of nearly all temperate, tropical and equatorial soils acting as an effective biocontrol agent by suppressing plant pathogens through antagonism, competition, and induction of host resistance. An advantage of using *Trichoderma* sp. over other biocontrol agents is the viability of the spores of this fungus over a considerable period of time, which makes this fungus an efficient agent under unfavourable climatic conditions. Efficient mass multiplication of *Trichoderma harzianum* depends on the availability of nutritionally enriched substrates that support rapid biomass production. Sorghum grain amended with neem, groundnut, mustard, and linseed oil cakes at 5, 10, and 20% concentrations was evaluated over incubation periods of 7, 14, and 21 days for colony-forming unit (CFU) production. CFU levels increased with incubation period across all treatments, with maximum values consistently recorded at 21 days. Among the amendments, mustard cake at 20% concentration produced the highest CFU ( $248.36 \times 10^6$ ), followed by groundnut cake ( $250.19 \times 10^6$ ), while linseed cake showed the lowest performance ( $196.25 \times 10^6$ ). Higher amendment levels generally enhanced CFU accumulation, indicating a positive nutrient effect. The results highlight the importance of substrate optimization, with sorghum amended with 20% mustard cake and incubated for 21 days identified as the most effective combination for large-scale multiplication of *T. harzianum*.

PP - 3

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## **Chitinolytic Bacteria from Vermicompost: Characterization and In-Vitro Biocontrol Activity**

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Extensive exposure to chemical pesticides over the years has resulted in severe health risks in humans, as well as the environment. It is imperative to find clean and sustainable alternatives to these hazardous pesticides. Using beneficial microorganisms as a mechanism of biological control of pathogens can reduce environmental and human health risks, as well as the chances of pathogen resistance. In this study, chitinase-producing bacteria were isolated from vermicompost, which is rich in nutrients as well as microbial diversity. The bacteria were characterized qualitatively and quantitatively for the production of chitinase. The isolate Chi4 produced the highest amount of chitinase (2.03µmol/ml) and was considered the best chitinolytic isolate. The stability and activity of the crude enzyme was tested under different temperature and pH conditions and highest activity was observed at 40°C and pH 6.0. In vitro antifungal and nematicidal assays were also performed with the isolate, which was found to be active against plant pathogenic fungi and nematodes, highlighting the potentiality of chitinase producers as prospective alternative to chemical pesticides.

PP - 4

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## **Integrated Microbial Approach for Managing Root-Knot Nematodes and *Ralstonia solanacearum* Complex in Brinjal**

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Brinjal (*Solanum melongena* L.) is an important vegetable crop worldwide, yet its productivity is constrained by the combined infestation of root-knot nematodes (*Meloidogyne incognita* race 2) and the bacterial wilt pathogen *Ralstonia solanacearum*. To manage this disease complex sustainably, a field experiment was conducted during 2017 and 2018 to evaluate the effectiveness of microbial combination. Results from both seasons showed that all treatments significantly superior over untreated control in fruit yield. Application of microbial combination markedly reduced second-stage juveniles(J<sub>2</sub>), with reductions ranging from 59.48 to 66% in 2017 and 19.05 to 44.95% in 2018. The highest brinjal fruit yield of

15.25 t/ha and 10.24 t/ha was recorded with carbofuran @ 1 kg a.i./ha combined with Streptomycin sulphate @ 4 g/L of water. This was followed by 15.10 t/ha and 10.00 t/ha in the treatment with FYM @ 1 t/ha enriched with Biofor pf-2 in 2017 and 2018 respectively.

PP - 5

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## Synergistic Action of Chitosan and Selected Antagonistic Fungi on Root-Knot Nematode (*Meloidogyne incognita*) Infecting Beetroot

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Root-knot nematode (*Meloidogyne incognita*) poses a severe threat to beetroot (*Beta vulgaris*) cultivation globally, causing significant yield losses. As chemical nematicides face increasing restrictions, sustainable management strategies are urgently needed. This study evaluated the individual and combined efficacy of chitosan with selected antagonistic fungi, *Pochonia chlamydosporia* and *Syncephalastrum racemosum*, against *M. incognita* in beetroot under pot conditions. All applied treatments substantially suppressed the root-gall infestation caused by *M. incognita*, and consequently increased plant growth, but combined treatments of chitosan with antagonistic fungi exhibited a pronounced synergistic effect. Chitosan combined with *S. racemosum* was the most effective, attaining the highest suppression in egg masses/root (48.9), eggs/eggmass (85.6), nematode population/250g of soil (719.2) and root-knot index (2.0), and the maximum enhancement in root length (15.7cm), fresh root weight (87.7g) and dry root weight (23.1g). This synergy is attributed to the dual mode of action: chitosan directly impairs nematode viability and stimulates plant systematic resistance, while the antagonistic fungi parasitize eggs and juveniles, produce nematicidal metabolites, and further induce plant defense. The findings conclusively indicate that integrating chitosan with bioagents offers a highly effective, eco-friendly strategy for the sustainable management of root-knot nematodes in beetroot cultivation.

PP - 6

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## Assessment of Native Microbial Efficacy as a Sustainable Method of Raising Tea Plants

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Tea plants, *Camellia sinensis* (L. O. Kuntze) belong to the family Theaceae. The tender leaves, shoots and buds are procured to manufacture tea. It is second most consumed

non-alcoholic beverage only after water, throughout the world. Tea, a valuable cash crop has massive socio-economical value globally. However, the occurrence of multiple diseases and abiotic stresses severely hampers tea plantations, thus causing deleterious effects on the tea industry. Dependence on excessive chemical fertilizers and pesticides in tea cultivation further deteriorates soil quality, ecological balance and long-term tea productivity. This research is mostly focussing on the rhizosphere soil as well as the phyllosphere as these are the habitation for diverse bacterial communities which can improve yield and quality of the resultant tea leaves. Bacteria were collected and isolated from both the phyllosphere and rhizosphere soil of the tea plants of the Experimental Tea Garden of 'Centre of Floriculture and Agri-Business Management (COFAM)', University of North Bengal (26.706215° N, 88.356097° E), West Bengal, India. Primarily, total twenty-eight (28) bacteria were isolated and then screened for various PGPR and Biocontrol properties. Among the twenty-three (23) isolates, three (3) bacterial strains named as B7, B8 and CS3 were proved to be most potential in terms of both PGPR and biological control activities. These microorganisms exhibited remarkable efficiency as nitrogen fixers and as solubilizers of phosphorus, potassium, and zinc. These strains effectively formed biofilms and produced key enzymes like cellulase, protease and chitinase. They also released certain volatile organic compounds such as hydrogen cyanide (HCN) and ammonia, and synthesized important phytohormones including gibberellic acid and indole-3-acetic acid (IAA). They were primarily identified on chromogenic agar media as members of the phylum *Firmicutes*. These indigenous bacterial isolates collectively may provide holistic protection to tea plants. On the basis of the initial study, the effective consortia will be prepared with zero negative interaction and will be applied in commercial fields. However, advanced molecular techniques must be employed to explore their microbial diversity and enable genetic manipulation.

PP - 7

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## **Application of Extremophilic Bacteria Isolated from Tsomoriri Lake, Ladakh in Biocontrol for Sustainable Agriculture**

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Phytopathogens, encompassing fungi, bacteria, viruses, and nematodes, pose a significant threat to the agricultural industry by causing substantial economic losses through severe plant diseases. The excessive use of synthetic fungicides to combat phytopathogens has raised environmental and human health concerns. This study aims to mitigate the problem utilizing enzymes secreted by polyextremophilic bacteria promoting extremophilic agriculture. Six bacterial strains (T1-T6) isolated from Tsomoriri Lake, Ladakh, exhibited remarkable resilience to extreme conditions, including high pH (upto 11.5), salinity (upto 16%) , temperature fluctuations (4°C to 60°C) , UV radiation (short UV of 240nm) , heavy

metals Iron (1000ppm) and Lead (2000ppm), and drought (7.5% PEG). Some strains produced melanin to shield against UV, showcasing their adaptability. These bacteria thrived under combined stress conditions, highlighting their poly-extremophilic nature. The bacterial strains were identified by 16srRNA sequencing as *Bacillus cereus* (T1, T2), *Lysinibacillus composti* (T3), *Micrococcus luteus* (T5), and *Pseudomonas* sp. (T4) and *Bacillus* (T6) by Hichrome UTI and Bacillus Agar screening. T1 and T6 showed multidrug resistance and metallothionein production. Strains T2 and T6 promoted plant growth through nitrogen fixation, nutrient solubilization, and IAA production, while T1 and T4 produced NH<sub>3</sub> while T4 also produced IAA and HCN. These strains secreted enzymes with biocontrol potential: Cellulase (T5) breaks down fungal cell walls, inhibiting phytopathogens. Amylase (T2) degrades starch, limiting nutrient availability, Pectinase (T4) breaks down pectin, facilitating bioherbicidal role against weeds. Laccase (all strains) oxidizes phenolic compounds, exhibiting antimicrobial activity. Lipase (all strains) disrupts cell membrane integrity, and, Gelatinase (T6) degrades proteins, exhibiting antimicrobial activity.

**PP - 8**

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## **Reviving Ghoramara: Soil Microbiome Solutions for a Drowning Island**

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Ghoramara Island is a rapidly shrinking landmass in deltaic regions of the Indian Sundarbans. Once a fertile agricultural hub with flourishing rice and betel cultivation, the island faced dramatic changes due to sea level rise, high salinity, and frequent cyclonic storms, which have severely degraded soil quality and shrunk the island from approximately 9 square kilometres in the 1970s to less than 4.5 square kilometres today, thus, creating a pressing need for sustainable solutions. Our study investigates scientific methods to restore agriculture on Ghoramara through a comprehensive study of soil samples from the island. Ten soil samples from various regions of Ghoramara Island were analysed for their physicochemical parameters, including pH, electrical conductivity and macro and micronutrients. Indigenous soil microorganisms were isolated from these samples and tested for their salinity tolerance. Their nutrient-solubilizing property and enzymatic potential was tested through various assays, thus highlighting their role in organic matter breakdown. Their antifungal properties were also tested. The findings indicated the presence of salinity-tolerant, enzyme-producing, fungus-inhibiting plant-growth-promoting microorganisms in the soil, suggesting their potential use in sustainable agricultural practices. Accordingly, a PGP microbial consortium was formulated using these native strains which have been applied for testing on the fields of Ghoramara for its efficiency in improving soil quality, and crop yield.

Long-term goals include scaling up of the consortium for large-scale applications. Educating the local farmers on such cultivation will be prioritised. It is hoped that the project would recreate agriculture in Ghoramara and also establish a replicable model for other deteriorated coastal ecosystems.

PP - 9

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## **Epidemiology, Pathogenic Variability and Plant Extract Based Management of Citrus Bacterial Canker Disease (Cbcd) in West Bengal**

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Citrus crops are widely cultivated in tropical and subtropical regions and contribute significantly to agricultural production and human nutrition. Citrus bacterial canker, caused by *Xanthomonas axonopodis* pv. *citri* (Xac), remains a major constraint to citrus production worldwide, including in West Bengal, India. Symptom variability and disease incidence were assessed in four citrus species—acid lime, Gandharaj lemon (*Citrus limon*), sweet orange (*Citrus sinensis*), and pummelo (*Citrus grandis*/*C. maxima*)—through roving surveys at four locations. Acid lime showed the highest Percentage Disease Index (PDI) (23.60%), followed by Gandharaj lemon (18.35%) and sweet orange (15.65%), while pummelo recorded the lowest PDI (10.15%). A fixed-plot study on acid lime revealed that disease severity was highest in September (41.4%) and August (36.2%) and lowest in December (6.4%), with a gradual decline from October onward, influenced by temperature, humidity, rainfall, and soil temperature. Pathogenic variability among Xac isolates showed isolate S6LT16 to be highly virulent, while S5LT15 was non-pathogenic; other isolates ranged from low to moderate virulence. Molecular confirmation using Xac-specific primers (XACF/XACR) identified all isolates as *X. axonopodis* pv. *citri*. In vitro evaluation of seven plant extracts demonstrated that Asian spider flower completely inhibited bacterial growth at 3 g concentration, while ivy gourd was effective at 6 g. Other extracts showed moderate to concentration-dependent inhibition. These botanicals significantly suppressed the pathogen in vitro, highlighting their potential role in eco-friendly integrated management of citrus bacterial canker.

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## Microbe Driven Sustainable Agriculture in Reclaimed Soil of East Kolkata Wetlands

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Wetlands represent the convergence of land and water, showcasing a rich ecological diversity and serving numerous functions. Ramsar Convention had recognized East Kolkata Wetlands of international significance in August, 2002. However, inefficient management of these wetlands has resulted in their gradual deterioration. In this investigation, soil samples were assembled from the reclaimed farmlands in the Chowbaga regions of the East Kolkata Wetlands. The soil physico-chemical specifications were analysed throughout three cropping stages namely, initial phase, peak phase, and intercropping phase of *Cucurbita maxima* and *Zea mays*. The metagenomic analysis of soil samples at various cropping stages was conducted to investigate the presence of residual bacterial flora and their interactions with soil properties. The plant growth-promoting characteristics of the key bacterial flora isolated from the rhizospheric areas of *Cucurbita* sp. and *Zea mays* were evaluated. Fungus infecting the leaves of *Cucurbita* sp. and *Zea mays* were isolated and ability of the bacterial isolates to work towards biological pest management were studied. Additionally, their capacity to produce biotechnologically significant enzymes such as lipase, lignin peroxidase, and amylase was also assessed. The reclaimed agricultural lands of East Kolkata Wetlands were found to possess high levels of heavy density metals, especially lead. Among the bacterial isolates, two of them demonstrated significant potential for lead mitigation, with the ability to adsorb around 5.24% and approximately 8.28% of lead, respectively. The selected bacterial isolates were utilized as a microbial consortium and applied to *Cucurbita maxima* and *Zea mays* cultivated in the reclaimed soil of the East Kolkata Wetlands, resulting in a reduction of lead content in the fruits of these plants by 92% and 10.7%, respectively. ANOVA studies have been done to decipher the significance of the impact of the bacterial consortia upon the treated plants with respect to the control plants. The possible use of PGPR has consistently grown, as it is found to work as a viable substitute for the ongoing reliance on chemical fertilizers and pesticides.

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## Chemical Ecology of *Meloidogyne graminicola* Embryogenesis

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Plant-parasitic nematodes are major pests of agricultural and horticultural crops, globally. Existing control methods mainly target post-hatch second-stage juveniles (J2s). However, the egg stage of these nematodes is metabolically active but immobile, making it potentially susceptible to chemical interference. Plant root exudates (REs) are previously known to influence nematode hatching and juvenile behaviour, yet their effect on embryogenesis is still unclear, specifically in case of Root-Knot Nematodes (RKNs). Therefore, the objectives of these research were to evaluate effects of REs from susceptible and resistant rice germplasms, as well as from healthy and nematode- infected plants on *Meloidogyne graminicola* egg hatching behaviour (Rice RKN). Preliminary results of egg hatch assays have shown that REs from the resistant rice cultivar (KB-213) delay their egg hatch rate. RE from nematode-infected and uninfected rice plants also possess differential effects on their egg hatching. However, which embryonic stage(s) are particularly influenced and the change in embryonic timeline is not known yet. In future, metabolomic profiling of REs will help to identify candidate bioactive compounds influencing embryogenesis. A transcriptome analysis of their embryos will reveal gene expression changes under different RE treatments. Targeting embryogenesis and egg hatching could therefore open new avenues for early-stage nematode management and will bring light to potential biochemical targets for environmentally safe, early-stage management of root-knot nematodes.

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## Evaluation of Plant-Derived Seed Protectants for Management of Pulse Beetle in Stored Red Gram

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Pulse beetle is a major storage pest of red gram causing severe seed damage, weight loss, and reduced viability. The present study evaluated six plant-derived seed protectants under ambient storage for six months over two consecutive years using a completely

randomized design with eight treatments, including an inorganic check and untreated control. Seed damage, weight loss, germination, and moisture content were recorded. All botanicals significantly reduced storage losses compared with the control. Neem oil and neem leaf powder consistently performed best and were comparable to the chemical check, particularly in minimizing seed damage and maintaining germination. Turmeric rhizome powder was least effective across parameters. The untreated control recorded maximum damage, weight loss, and moisture accumulation with lowest germination. These results demonstrate the potential of neem-based botanicals as eco-friendly alternatives to synthetic insecticides for protecting stored red gram.

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## **Toward Resilient Agriculture: Policy Perspectives on Plant Nematode Threats**

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Plant-parasitic nematodes represent a significant yet often underestimated threat to global agriculture, causing substantial yield losses across major crops. These microscopic organisms damage plant roots, disrupt nutrient and water uptake, and predispose crops to secondary infections, collectively undermining food security and farmer livelihoods. Addressing nematode threats requires a multidimensional policy approach aimed at building resilient agricultural systems. Key strategies include strengthening biosecurity measures and quarantine protocols to limit pest spread, promoting early detection through diagnostic laboratories and farmer awareness programs, and incentivizing integrated pest management practices. Research and innovation form a critical pillar of resilience, encompassing the development of resistant crop varieties, biological control agents, and precision diagnostic tools that minimize reliance on chemical nematicides while safeguarding environmental and human health. Sustainable management is further enhanced through diversified cropping systems, soil health improvement, and climate-adaptive practices such as conservation agriculture and ecosystem-based approaches. Policies should also focus on equitable access to resources, particularly for smallholder farmers, enabling adoption of resilient practices and technologies. In summary, plant nematodes pose a complex challenge that intersects agronomy, environmental sustainability, and socio-economic development. Effective policy frameworks must integrate prevention, management, research, and capacity-building to mitigate nematode threats while promoting resilient and sustainable agricultural landscapes.

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## Effect of Fungicides and Plant Spacing for Management of Leaf Spot and Flower Blight Disease of African Marigold (*Tagetes erecta* L.)

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African marigold (*Tagetes erecta* L.) is an important commercial loose flower crop cultivated extensively in India for ornamental, religious and industrial uses. Despite its wide adaptability, marigold production is severely constrained by fungal diseases, among which leaf spot and flower blight caused by *Alternaria* spp. are predominant during the *Kharif* season, resulting in considerable yield and quality losses. An integrated approach involving cultural and chemical management is essential for effective disease management. A field experiment was conducted during the *Kharif* season of 2022 at the Regional Research Station, Jhargram (Red and Laterite zone of West Bengal), to study the effect of plant spacing and fungicide application on the management of *Alternaria* leaf spot and flower blight in African marigold cv. Bidhan Gold. The experiment was laid out in a split plot design with four plant spacings (30cm×30 cm, 30cm×45 cm, 30 cm×60 cm and 45cm×45 cm) as main plot treatments and four fungicidal treatments (water spray, Thiophanate methyl, Propiconazole and Pyraclostrobin) as sub-plot treatments, with three replications. Disease severity was recorded using a (0–5) scale and expressed as Percent Disease Index (PDI), and disease progress was quantified through Area Under Disease Progress Curve (AUDPC). Results revealed that wider spacing significantly reduced disease severity, with the lowest PDI and AUDPC recorded at 45cm×45 cm spacing. Among fungicides, Pyraclostrobin was found to be the most effective in suppressing flower blight, followed by Propiconazole. However, the highest total flower yield was obtained at 30cm×45 cm spacing. The interaction of 30cm×45 cm spacing with Pyraclostrobin application produced the maximum flower yield. The present findings indicate that adoption of optimal spacing coupled with effective fungicidal management offers an efficient strategy for minimizing *Alternaria* blight while maximizing marigold productivity.

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## Genetic and Pathogenic Variability of *Sclerotium rolfsii* Under Gangetic Alluvial and Red & Lateritic Agro-Ecological Regions of West Bengal

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*Sclerotium rolfsii* Sacc. is a highly destructive soil-borne pathogen causing southern blight and collar rot in a wide range of agricultural and horticultural crops. A comprehensive study was conducted at Bidhan Chandra Krishi Viswavidyalaya, West Bengal, to investigate the morphological, pathogenic and genetic variability of *S. rolfsii* under Gangetic alluvial conditions. Field surveys across multiple districts revealed disease incidence ranging from 4 to 28%, with lentil, elephant foot yam, tomato, cowpea, and chickpea identified as highly susceptible hosts, whereas cruciferous vegetables exhibited comparatively lower disease incidence. Twenty-five isolates were collected and analyzed for cultural, morphological, pathogenic, and biochemical traits. Considerable diversity was observed in mycelial growth, biomass production, and sclerotial characteristics. Pathogenicity assays categorized isolates into four virulence groups: low (20%), moderate (28%), medium-high (16%), and high virulence (36%). Mycelial growth rate, sclerotial production, and oxalic acid production were strongly correlated with pathogenicity ( $r = 0.704^{**}$ ,  $0.667^{**}$ , and  $0.794^{**}$ , respectively). Together with mycelial protein content, these factors explained 85.8% of the variation in virulence. Host-specific responses revealed tuberose and lathyrus isolates as prolific sclerotia producers, while cauliflower isolates were least prolific. Molecular characterization using MCG, UP-PCR, and RFLP markers revealed high genetic diversity, with UP-PCR banding patterns correlating with virulence traits. Overall, oxalic acid production, mycelial growth, sclerotial production, and protein content were identified as key determinants of pathogenic variability. The pronounced phenotypic and genotypic diversity of *S. rolfsii* populations in West Bengal underscores their role in host susceptibility and disease epidemiology. Crop rotation involving cruciferous vegetables is suggested as a potential strategy for reducing pathogen inoculum, contributing to sustainable management of southern blight in the Gangetic alluvial region.

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## **Influence of Weather Factors on the Population Dynamics of Major Insect Pests of Maize and Their Natural Enemies**

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A field experiment was carried out during the *Rabi* season of 2020–21 at the central research farm of Bidhan Chandra Krishi Viswavidyalaya, Gayeshpur, Nadia, West Bengal, to study the relationship between insect pest populations of maize, their natural enemies, and weather parameters. Populations of major pests, such as fall armyworm and corn aphid, and minor pests, such as red cotton stainer and rugose spiralling whitefly, along with natural enemies, were recorded at weekly intervals following standard meteorological weeks throughout the crop season. Correlation coefficients were worked out between major pest population densities and weather parameters, including maximum and minimum temperature, morning and evening relative humidity, sunshine hours, wind speed, and total rainfall. The study revealed a significant positive correlation of fall armyworm with minimum temperature. Aphid population showed significant positive correlation with maximum and minimum temperature and total rainfall, while a significant negative correlation was observed with morning relative humidity. Natural enemy abundance was positively correlated with maximum temperature. The findings emphasize the influence of weather parameters on pest and natural enemy populations, supporting weather-based pest forecasting and IPM strategies.

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## **Epidemiology and Management of Rust of Grapevine in the Red and Lateritic Region of West Bengal**

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Grapes (*Vitis vinifera* L.) are a major commercial fruit crop, grown extensively in temperate, subtropical, and tropical regions all over the world. Significantly, it holds the fifth position among fruit crops in India, covering an area of 199,000 hectares, with a production of 2,585,000 tonnes and a productivity of 19.1 tonnes per hectare. Grapes are a refreshing fleshy fruit, abundant in natural sugars and particularly rich in vitamin C. They are a good source of glucose, proteins, essential vitamins, amino acids, lecithin, and various minerals. In this current era of global climate change, grapevines in India are found to be highly susceptible to biotic stresses, specifically caused by fungi, which affect leaves and berries, reducing yield and fruit quality. Anthracnose, downy mildew, powdery mildew, and rust are some of the commonly reported grapevine diseases. In West Bengal though grape is not so far a popular commercial fruit crops among the farmers but cultivation has been recently started in fewer pockets specially in the dry regions of this state. The disease severity of Rust in 2023-24 & 2024-25 reveals with a range of 20.42-48.70% and severity was positively correlated with Relative humidity (RH. max = 0.396, RH. min = 0.236) and negatively with temperature and rainfall (T. max = -0.772, T. min = -0.425 & Rf = -0.045). Efficacy among different fungicides under natural field conditions revealed that Azoxystrobin 8.3% + Tebuconazole 18.3% SC (Custodia) was found to be the most effective, with the lowest AUDPC value (199.50) and the highest disease reduction (66.67%) against rust of grapevines. Cyflufenamid 5% EW demonstrated the highest efficacy also in enhancing grape yield (62.82%) against powdery mildew of grapes.

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## Patho-Complex Association of Shoot Dieback and Gummosis Disease of Cashew in West Bengal

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Cashew is an important high valued drought-tolerant plantation crop mainly cultivated in the coastal states of India including West Bengal. However, its productivity is severely constrained by destructive fungal diseases, notably shoot dieback caused by *Diaporthe* spp. and gummosis associated with *Botryosphaeria* spp. Shoot dieback and gummosis were found to be the major prevalent diseases in orchard with 95 and 55% disease incidence, respectively. In addition to external symptoms wedge shaped brown discolouration on xylem differentiated dieback from gummosis. Based on ITS sequence, 18 isolates of *Diaporthe* sp. and 22 isolates of *Botryosphaeria* sp. were identified and Phylogenetic analysis separated all the isolates of *Diaporthe* sp. into two major clades whereas all the *Botryosphaeria* sp. was placed in a single clade. Selective pruning and removal of the diseased shoot debris from the orchard proved to be effective for management of shoot die back and gummosis. Adoption of pruning along with plant debris management in orchard significantly reduced the dieback severity and resulted highest nut yield as compared to the plot treated with selective pruning, debris management as well as control. There was a consistent reduction of disease severity as well as area under disease progress curve (AUDPC) in both the years. Pooled analysis of data revealed that T<sub>1</sub> (pruning + debris management) showed lowest disease severity (32.92%) of shoot dieback and AUDPC (6743.75) followed by T<sub>2</sub> (pruning only). Pooled data of annual nut yield, number of panicles m<sup>-2</sup> and number of nuts m<sup>-2</sup> were also significant. AUDPC was also significantly negatively correlated with annual nut yield, number of panicles m<sup>-2</sup> and number of nuts m<sup>-2</sup>. Application of Carbendazim + mancozeb has shown highest reduction of gummosis disease severity ranging from 34.23% in Bhaskara to 45.04% in Ullal-4 followed by Trifloxystrobin + Tebuconazole, where it ranged between 25.82% in Bhaskara and 38.44% in Ullal-4.

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## Assessment of Plant Extracts on Enzymatic Responses in Brinjal against Root-Knot Nematode, *Meloidogyne incognita*

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Root-knot nematode, *Meloidogyne incognita* is predominant in vegetable growing areas cause to severe yield losses by damaging roots, leading to reduced plant growth and fruit quality in brinjal crop. In India, *M. incognita* causes about 21% yield loss in brinjal, resulting in estimated annual agricultural losses of approximately ₹210 crore. A pot culture experiment was conducted under cage house at the Department of Nematology, MPUAT, Udaipur, Rajasthan during kharif, 2022 to evaluate the efficacy of botanical extracts on enzyme determination in Brinjal (Var. BR-112). The experiment consisted of six treatments with Completely Randomized Design (CRD) with four replications. The treatments included seedling deep treatments @10% of T<sub>1</sub>- Tulsi (*Ocimum tenuiflorum*), T<sub>2</sub>- Pyrethrum (*Chrysanthemum cinerariaefolium*), T<sub>3</sub>- Datura (*Datura stramonium*), T<sub>4</sub>- Ashwagandha (*Withania somnifera*), T<sub>5</sub>- Congress grass (*Parthenium hysterophorus*) and T<sub>6</sub>- Untreated control. The findings indicated that all treatments significantly enhanced defence related enzyme activities compared to the control. Enzymatic observations on Peroxides (PO), Polyphenol oxides (PPO) and Phenylalanine ammonium lyase (PAL) were recorded at 14 and 28 days after seedling treatment. Among the treatments, seedling dip with Datura (T<sub>3</sub>) at 10 per cent concentration exhibited the highest enzyme activity (PO, PPO and PAL) at both observation intervals, (4.007 µmol/min/gm, 0.024 µmol/min/gm 0.233 µmol/min/gm) (5.014 µmol/min/gm, 0.033 µmol/min/gm, 0.364 µmol/min/gm), while minimum (1.754 µmol/min/gm, 0.007 µmol/min/gm and 0.079 µmol/min/gm) (2.176 µmol/min/gm, 0.010 µmol/min/gm and 0.094 µmol/min/gm) was recorded in check at 14 and 28 days respectively. In conclusion, all the botanical extracts at 10% concentration increased PO, PPO and PAL activities in brinjal plants infected by root-knot nematode. Plant extracts are able to activate the plant's defense system against the nematodes and they can directly reduce the nematode population, thereby improving plant health and yield.

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## Hidden Invader in the Hive: Morphological and Biological Characterization of *Megaselia scalaris* (Loew), an Emerging Threat to *Apis mellifera* (Fabricius)

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The humpbacked or scuttle fly, *Megaselia scalaris* (Loew, 1866) (Diptera: Phoridae), is a polyphagous, facultative endoparasitoid known to infest colonies of western honey bee *Apis mellifera* Linnaeus (1758) (Ricchiuti *et al.*, 2016; Debnath & Roy, 2019). Although this opportunistic detritivore is a potential threat to foraging pollinators, its role in exacerbating honey bee colony collapse and facilitating pathogen transmission has been under-explored. The present study examined the morphology and biology of *Megaselia scalaris*, impeding growth in commercial apiculture. Healthy honey bees were collected by sweeping, whereas parasitized individuals—alive but fallen near light sources with rigid, unfolded wings—were sampled at biweekly intervals from November 2022 to May 2023 at the BCKV, Mohanpur campus. All specimens were reared in sterilized test tubes under controlled conditions (30 ± 2°C; 65–75% relative humidity) with cotton plugs for ventilation. Nutritional requirements were met using cotton soaked in sucrose solution. Emerging larvae were transferred to separate tubes to avoid overcrowding, and pupae were subsequently moved to clean containers until adult emergence. Adult flies were maintained on either fresh *A. mellifera* specimens or sucrose-soaked cotton. Honey bee samples were routinely examined under an Olympus SMZ-2T microscope to identify parasitized eggs, particularly on the abdomen. Each developmental stage, from larval instars to pupae and adults, was preserved individually in 80% ethanol. Morphological assessments encompassed sexual dimorphism, larval growth patterns, mouthpart structure, and morphometric measurements. Adult phorids were identified to species level using the taxonomic keys of Disney *et al.* (1994). The study identified clear male sexual dimorphism marked by microtrichia on the labellum, while wing venation and frontal bristle patterns confirmed species identity. Spiracle structure, tubercle formation and papillae development enabled accurate instar differentiation and mouthpart morphology clarified host exploitation mechanisms. The study elucidated the infestation dynamics of *Megaselia scalaris* and its impact on apiary health and foraging behavior, generating baseline information for the formulation of sustainable pest management strategies in apiculture. A clear understanding of species identification and life cycle biology of *M. scalaris* may support habitat assessment, documentation of new host-parasitoid relationships and foster the development of effective biocontrol strategies, addressing existing key gaps in integrated apicultural pest management.

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## **Dynamics of Tea Rhizosphere in Sustainable Tea Production**

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Tea is the second most highly consumed non-alcoholic beverage throughout the World. It is valued for its socio-cultural and huge economic significance. Tea is manufactured from the leaves, leaf buds and internodes of numerous sub-varieties of the *Camellia sinensis* (L. O. Kuntze) plants belonging to the family *Theaceae*. However, the major concerns of tea cultivation are both biotic and abiotic stresses which greatly decrease yields and lead to greater dependence on harmful chemical fertilizers and pesticides. In this investigation, rhizosphere soil samples were collected from tea plants of Experimental Tea Garden of Centre of Floriculture and Agri-Business Management (COFAM), University of North Bengal (26.706215° N, 88.356097° E). A total of eleven (11) bacterial isolates were obtained from the tea rhizosphere soil samples and screened for growth-stimulating properties and biocontrol activity. Out of them, five isolates named TS1, TS2, CS1, CS3 and CS8 were proved to be the most promising, showing NPK (nitrogen, phosphorus, potassium) and zinc solubilisation, biofilm production, HCN production and cellulase enzyme activity. Antibiotic sensitivity assay and haemolytic activity on blood agar were also tested. Cross-streak assay revealed that the selected isolates could coexist, providing the potential for utilizing them as a synergistic microbial consortium. Further, thorough research can determine the role of these bacteria as potent PGPRs and their role as biocontrol agents providing a holistic protection against pathogen attacks. Thus, in future these bacterial strains can be used effectively with the aim of creating a bioformulation commercially, with increased yield and replacing harmful chemical fertilizers with this cost-effective environment friendly alternative, offering a solution for sustainable tea plant production.

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## **The Rolling Circle Pathogen Prevention in the Reclaimed Agricultural Wetlands of East Kolkata**

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The East Kolkata Wetlands (EKW), a 12,500-hectare Ramsar site, functions as a natural sewage treatment and aquaculture system. This study investigated plant growth-promoting (PGP) properties of bacteria isolated from the rhizosphere of *Zea mays* (corn)

plants collected from Choubaga, EKW. Six bacterial strains (SCR-1 to SCR-6) were isolated and identified. All six strains exhibited phosphate solubilization. Nitrogen fixation was observed in SCR-1, SCR-5, and SCR-6, while potassium solubilization was seen in SCR-1, SCR-3, SCR-5, and SCR-6. Auxin production was measured after 24 and 48 hours. SCR-1 showed the highest auxin production at 24 hours (0.93 µg/ml), while SCR-4 showed the highest at 48 hours (4.18µg/ml). Quantitative assay of industrially important enzymes, biofilm assay and siderophore production ability of the bacterial isolates were also performed. Corn leaves were infected with white rust fungus. SCR-1, SCR-3, SCR-5, and SCR-6 demonstrated antifungal activity against this fungus. Volatile organic compounds (VOCs) produced by all strains inhibited fungal growth by 51.76%. SCR-1, SCR-5, and SCR-6 exhibited the most promising PGP properties. Consortia were developed after T-tests revealed that SCR-1 inhibited SCR-6. Two consortia, SCR-1 with SCR-5 and SCR-5 with SCR-6, were prepared. Corn plants treated with the SCR-1 and SCR-5 consortia showed a 21.5% increase in growth compared to those treated with the SCR-5 and SCR-6 consortia. 16s rRNA sequencing of these three isolates were done. SCR-1 is *Priestia megaterium*, SCR-5 is *Bacillus megaterium*, SCR-6 is *Bacillus mycoides*. This research demonstrates the potential of these bacterial isolates, particularly SCR-1 and SCR-5, as biofertilizers and biocontrol agents for corn. Further investigation is warranted to explore their application in sustainable agriculture within the unique EKW ecosystem.

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## Agriculturally Intelligent Bacteria from the Pangong Tso

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The Pangong Tso is a high-altitude brackish water lake extending from eastern Ladakh in India to western Tibet. It is situated at an elevation of 4225 m. It is a part of the Himalayan cold desert ecosystem. High-altitude lakes are comparatively pristine with a unique mixture of microbial diversity selected by severe environmental pressures that reduce species richness and increase prokaryotic dominance. The lake ecosystem is subjected to severe environmental stresses including multiple freeze-thaw cycles, high salinity, exposure to ultraviolet radiation and very low nutrient content. The lake water is alkaline in nature. Our study mainly aims to understand the biocontrol efficacy of culturable *Micrococcus luteus* and *Pseudomonas stutzeri*, from the lake ecosystem of Pangong Tso. They can withstand the ultraviolet radiation due to production of the pigments carotenoid and melanin, respectively. They have shown growth at high salt concentrations (up to 12%) and at alkaline pH. *Micrococcus luteus* has also shown production of volatile organic compound (VOC) HCN which inhibits the growth of fungi (*Fusarium sp.*). Due to this property, it can be exploited as a potential biocontrol agent. *Micrococcus luteus* and *Pseudomonas stutzeri* have been found

to inhibit the growth of several other plant pathogenic fungi. Production of siderophores, enzymes like protease aid them in their biocontrol mechanisms. More qualitative and quantitative assays are underway to explore the scope of its biocontrol efficacy. The microorganisms of the cold habitat have drawn tremendous attention due to the complex secondary metabolisms assisting their survival, adaptation, and evolution. Perhaps these cold habitats could be a rich source of new taxa, genes, and metabolites with remarkable biotechnological applications.

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## **Study on Impact of Conservation Agriculture Practices on Soil Meso-Arthropods Population in Rice-Black Gram-Mustard Cropping Sequence**

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Soil meso-arthropods play a pivotal role in nutrient cycling, organic matter decomposition, and regulation of soil biological processes, thereby contributing significantly to soil health and agroecosystem sustainability. However, their response to conservation agriculture (CA) practices under diversified cropping systems remains inadequately explored in Eastern India. The present investigation evaluated the impact of conservation agriculture practices on the diversity, abundance, and community composition of soil meso arthropods under a rice-black gram-mustard cropping sequence. Field experiments were conducted at the Central Research Farm, Bidhan Chandra Krishi Viswavidyalaya, Gayeshpur, West Bengal, India, during October 2022 to March 2023, comprising three tillage systems: conventional tillage, reduced tillage, and zero tillage, combined with varying levels of nutrient management and crop residue retention. Soil samples were collected at different crop growth stages and processed using the Berlese Tullgren funnel extraction method, a widely accepted technique for soil micro and meso faunal studies. Population density, group wise abundance, and Shannon diversity index were employed to assess soil arthropod community structure. The results revealed a strong influence of tillage intensity and residue management on soil meso arthropod populations. Zero tillage with 75% recommended NPK fertilizer and 100% crop residue retention recorded the highest mean meso arthropod density (3.01 individuals per 10 g soil), followed by reduced tillage with similar residue incorporation, whereas the lowest population was observed under conventional tillage with 100% NPK and no residue application. Among the cropping systems, black gram supported the highest meso arthropod abundance, followed by rice, while mustard exhibited comparatively lower populations. Mites (Acari) and springtails (Collembola) were the dominant groups, collectively constituting nearly 60% of the total soil meso arthropod fauna. Higher Shannon diversity

indices under zero and reduced tillage systems indicated enhanced habitat stability and biological resilience under CA practices. The study underscores that reduced soil disturbance, residue retention, and optimized fertilizer application foster soil arthropod diversity and abundance, emphasizing the ecological and agronomic benefits of conservation agriculture in rice-based cropping systems.

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## **Microbiome of Root-Knot Nematodes: Diversity and Functional Roles in *Meloidogyne* Pathogenesis and Biological Control**

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The functional roles of gut microbiota across diversified insect taxa have been thoroughly characterized. These symbiotic bacteria are known to have helped in improving overall host fitness through nutrient acquisition, detoxification of metabolites, immune modulation, etc. Insects have found to harbor well-structured microbial communities that are integral to their development and ecological adaptation. In contrast, similar studies on the functional roles of gut microbiota in root-knot nematodes (RKNs) are strikingly limited despite their immense agricultural importance and global distribution. Although recent studies have tried to identify the diverse bacterial taxa associated with RKNs but they focus on taxonomic profiling rather than functional characterization. As a result, the cause behind their presence or contribution to the overall fitness of the host remains unanswered. By integrating insights from studies associated with insect's core microbiota this proposed research aims to explain the need for metabolomic approaches to establish the causal relationships of RKN associated microbiota.

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## **Impact of Antixenotic Mechanism of Green Gram (*Vigna Radiata* L.) on Aphid Incidence in the Gangetic Plains of West Bengal**

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In India, green gram (*Vigna radiata* L.) is the third most crucial pulse crop after chickpea and pigeonpea. At every stage of the crop cycle, from seeding to storage, insect pests attack mungbeans and severely reduce crop productivity. This situation along with the

increased use of toxic chemicals for their management prompts the researchers to divert their efforts to Integrated Pest Management (IPM) which includes the use of resistant varieties. Specific genotype of any crop bears distinguished biophysical and biochemical parameters which have definite impact on the occurrence and distribution of crop pests. In this context, to study the impact of crop morphology on the incidence of pulse aphid (*Aphis craccivora*), an experiment was undertaken during summer season for consecutive two years in the university farm considering five germplasms of green gram of which two were released varieties (Sukumar and Virat) and rests were promising lines but not released yet viz. BCM 20-46, BCM 20-47, BCM 21-133. Trichome density of leaf and pod, total number of pod and plant height showed significant negative correlation with aphid incidence whereas total number of primary branches showed significant positive correlation. Pod length showed non-significant negative correlation whereas pod width revealed non-significant positive correlation. Regression analysis revealed that the trichome density on leaf and trichome density of pod described the aphid population up to 85% and 81% during the experimental years, respectively.

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## **Incidence of Major Sucking Pests of Mulberry (*Morus alba* L.) and Their Correlation with Weather Parameters in Bihar**

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Sericulture is an important rural-based agro-industry in India, integrating agriculture and industry while providing sustainable livelihood opportunities with relatively low investment and quick returns. The present investigation was conducted at the Advanced Centre on Sericulture, Dr. Kalam Agricultural College campus, Kishanganj, Bihar, during March to August 2023 to assess the incidence of major sucking pests of mulberry (*Morus alba* L.) and their relationship with prevailing weather parameters. The experiment was laid out in a Randomized Block Design using mulberry variety C-2038. Field observations revealed the occurrence of three major sucking pests: mealy bug, thrips, and whitefly. Among these, mealy bug emerged as the predominant pest. The lowest mealy bug population (0.33 insects per top 10 cm twig) was recorded during the first fortnight of March, whereas the highest population (57.22 insects per top 10 cm twig) was observed in the last week of July. Thrips population peaked during the last week of March (16.48 per five leaves) and declined to its minimum in the last week of May (3.80 per five leaves). Whitefly incidence was highest in the last week of July (77.25 per top 10 cm twig) and absent during the first week of March. Correlation analysis indicated a significant positive association of whitefly and mealy bug populations with minimum temperature and relative humidity, whereas thrips population

showed a significant negative correlation with these parameters. Other weather factors exhibited no significant influence. The findings emphasize the role of climatic factors in pest dynamics and highlight the importance of developing climate-responsive sustainable pest management strategies.

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## **Agroecology to Climate Resilience: Ecological Research and Future Directions**

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Prof. Parthiba Basu's research advanced understanding of how biodiversity functions within human-dominated landscapes, particularly smallholder agricultural systems of South Asia. Over more than two decades, his work investigated pollinators, avian frugivores, herpetofauna, ants and other faunal communities across disturbance, urbanization and agricultural intensification gradients to understand how biodiversity and ecosystem functions respond to farming practices and landscape structure. His studies demonstrated that heterogeneous, low-intensity farms can act as ecological refugia supporting diverse ecosystem-service providers. By linking animal behaviour, community interactions and habitat structure with crop production, this research showed that ecosystem services depend jointly on farm management, surrounding vegetation and environmental stressors such as pesticides and pollution. The research bridged fundamental community ecology with applied conservation, positioning agroecology as a practical pathway for sustainable agriculture.

His final major collaborative initiative, **SIFS-CLIM (Sustainable Integrated Farming Systems for Climate Mitigation and Adaptation)**, extends this vision toward climate resilience. The project evaluates integrated farms combining crops, trees, livestock and nutrient recycling, testing whether they outperform conventional systems in resource efficiency, biodiversity support, productivity and nutritional security. Early observations suggest greater abundance of pollinators and natural enemies in long-established integrated farms, indicating improved ecosystem stability.

Future research building on his legacy aims to integrate biodiversity, climate change and farmer livelihoods into predictive frameworks for climate-smart agriculture. Together, these efforts position agroecological farming systems not only as biodiversity refuges but also as scalable solutions for resilient food production under global environmental change.

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## Sustainable Pest Management Strategies for Soybean in Storage: Advances, Challenges, and Future Research Directions

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Post-harvest deterioration of soybean [*Glycine max* (L.) Merrill.] during storage poses a significant threat to seed quality, nutritional integrity, and economic returns, particularly in regions where traditional storage systems predominate. Weight loss, decreased germination, and deterioration of protein and oil content are all caused by insect pests, particularly bruchids (*Callosobruchus* spp.), as well as secondary microbial contamination. The evidence from recent studies and review papers looking at sustainable pest management techniques for stored soybeans within an Integrated Pest Management (IPM) framework is summarised in this study. Laboratory bioassays, controlled storage trials, evaluations of seed vigour and quality, biochemical analyses, and comparisons of chemical and non-chemical interventions were all used in the evaluated studies. The identified sustainable strategies include use of inert dusts like diatomaceous earth, botanical insecticides (plant extracts and essential oils), entomopathogenic fungi (*Beauveria bassiana*, *Metarhizium anisopliae*), sensor-based monitoring tools, hermetic storage technologies (e.g., triple-layer bags), and modified atmospheres. Evidence suggests worries about resistance development, residue accumulation, and environmental impact, even though traditional fumigants like phosphine are still effective in reducing infestation. Physical and biological approaches, on the other hand, show encouraging effectiveness with better safety profiles and lower ecological risk. There are still significant gaps in the field despite increased attention. Practical implementation is hampered by a lack of large-scale field validation, a lack of botanical formulation standardisation, a lack of integration of digital monitoring technology. To improve sustainable soybean preservation and fortify post-harvest food security, future research should prioritize multidisciplinary, field-oriented validation of eco-friendly interventions and integration of smart storage technology.

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## **Green Alternatives for Crop Protection in Millet Crops: Integrating Biological and Digital Innovations for Sustainable Pest Management**

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Insect pests pose a major constraint to millet production, compromising crop resilience and productivity despite their inherent tolerance to harsh environments. Millets such as Sorghum, pearl millet, barnyard millet and finger millet are vital staples in semi-arid and arid regions, contributing significantly to nutritional security and supporting millions of smallholder farmers. However, pests including stem borers, shoot flies, aphids, and armyworms cause substantial yield losses across the crop growth stages, leading to economic instability in rural communities. But excessive use of chemical pesticides has intensified ecological imbalance, environmental contamination, health hazards, and pest resistance. This presentation proposes a holistic crop protection framework integrating biological and digital innovations within an Integrated Pest Management (IPM) paradigm. Biological interventions include microbial biopesticides (*Bacillus thuringiensis*, *Azospirillum* sp., *Trichoderma* sp., entomopathogenic fungi), neem-based botanicals (*Azadirachta indica*), conservation of natural enemies, and host plant resistance. These eco-friendly strategies promote biodiversity conservation, soil health maintenance, and long-term pest suppression. Complementary digital tools—such as UAV-based remote sensing, IoT-enabled microclimate monitoring, artificial intelligence-driven pest forecasting, mobile-based decision support systems and water rationing—enable real-time surveillance, early detection, and threshold-based interventions. The synergy between biological agents and precision digital technologies enhances targeted application, reduces indiscriminate pesticide use, improves input-use efficiency, and strengthens traceability of residue-safe millet produce. This integrated approach supports environmentally sound, economically viable, and climate-resilient millet production systems.

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## **Harnessing Banyan Prop Root Endophytes for Next-Generation Green and Sustainable Pest Management**

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*Ficus benghalensis* (banyan tree) shows extensive branching and development of prop roots and this unique growth pattern can be attributed to the complex interplay between various plant growth promoting hormones and the resident endophytic bacteria. This study focuses on the characterization of bacteria isolated from an actively growing prop root of *Ficus benghalensis* and their potential application in eco-friendly biofertilizer, biocontrol solutions, vegetative propagation and tissue culture. Five different endophytic bacterial colonies were isolated from a surface-sterilized growing prop root and identified as gram-positive *Bacillus* species. The bacteria were screened for several plant growth promoting traits such as indole-3-acetic acid (IAA), ammonia production, siderophore formation as well as their ability to solubilize nutrients like nitrogen, phosphate, zinc, potassium, etc. to which positive results were obtained. The enzyme analysis showed high levels of extracellular enzyme activity of the bacteria indicating fungal suppression through their enzymatic and metabolic functions. The production of cellulase and pectinase enzymes leads to the destruction of fungal cell walls, ammonia production and urease-based pH adjustments result in the creation of harmful conditions in the rhizosphere. The process of siderophore-based iron collection leads to competitive nutrient exclusion which prevents fungal growth. The bacterial organisms use catalase activity as a mechanism to withstand oxidative stress, which enables their bacteria to maintain continuous root colonization. By coupling nutrient cycling with pathogen suppression, these endophytes operate as both ecological engineers and endophytic soil dressers. This multifunctionality positions them as promising candidates for next-generation biofertilizer-biocontrol formulations aimed at green and sustainable pest management technologies. Future prospects include evaluating their efficacy in vegetative propagation and tissue culture systems to enhance rooting and plant establishment, extending their application beyond field-based pest management.

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## Response of field pea varieties infested with *Spodoptera litura* L. and *Helicoverpa armigera* Hub. based on biochemical components

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The study was carried out at the District Seed Farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal (India). Seventeen field pea varieties were evaluated under field conditions during the winter seasons of 2022–23 and 2023–24 to determine their resistance to the foliar pest *Spodoptera litura* (L.) and the pod borer *Helicoverpa armigera* (Hub.). For tobacco caterpillar infestation, weekly observations on percent leaf damage and larval population per plant were recorded. In the case of pod borer, larval population per plant and percent pod damage were assessed. During peak pest incidence, selected antioxidative enzymes, Peroxidase (POD) and Catalase (CAT) were estimated from selected varieties. Additionally, total chlorophyll, total carbohydrates, protein, and total phenol contents were analyzed. Significant variation was observed among the varieties in terms of enzymatic activity and biochemical constituents. Varieties such as HFP 1817, Pant P 523, IPF 21-16, and Pant P 517 showed significantly higher enzymatic activity, whereas SKNP 04-09, VL 42, HFP 1811, and HUDP 15 exhibited relatively lower activity. Higher protein content was recorded in SKNP 04-09, IPFD 21-4, HFP 1709, Pant P 509, VL 42, and Pant P 514. Carbohydrate content was notably higher in HUDP 1802, Pant P 514, VL 42, IPF 21-16, and Pant P 523. Phenol content was significantly greater in Pant P 523, HFP 1709, Pant P 509, and HFP 1811. The findings revealed significant differences among varieties regarding pest incidence and damage levels. Peroxidase and catalase activities in leaves were significantly and negatively correlated with leaf damage and pest population. In contrast, protein, carbohydrate, and chlorophyll contents showed a positive association with pest population and leaf damage, while total phenol content exhibited a significant negative correlation with both pest population and damage. Overall, the results suggest that biochemical constituents and antioxidative enzymes play a crucial role in conferring resistance to field pea varieties against these pests.

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Agricultural and Ecological Research Unit, Indian Statistical Institute, Kolkata, India*

***Shashya Suraksha* Best M.Sc.  
Thesis Competition Award**

## Dynamics of *Alternaria* Leaf Blight of Mustard in Relation to Weather Variables and its Eco-Friendly Management

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Indian mustard (*Brassica juncea* L.) is a major oilseed crop in India, cultivated over 8.06 million hectares with an annual production of 11.75 million tonnes. However, its productivity is adversely affected by foliar diseases, particularly *Alternaria* leaf blight (ALB), caused by *Alternaria brassicae*, which can cause yield losses up to 47%. Other associated pathogens such as *Erysiphe cruciferarum* (powdery mildew) and *Albugo candida* (white rust) also contribute significantly to the reduction in productivity. The present investigation was carried out to study the dynamics of *Alternaria* leaf blight in relation to weather variables and its eco-friendly management. The objectives were to (1) screen mustard germplasm for disease resistance, (2) evaluate the effect of sowing dates and nutrient management, (3) assess efficacy of botanicals and chemical inducers, and (4) develop disease-weather models for prediction.

Field experiments demonstrated that sowing date had a significant influence on disease development and crop yield. Early sowing on October 18 resulted in the lowest severity of ALB (33.20%), AUDPC (241), and powdery mildew incidence (7.11%), whereas delayed sowing on December 2 increased ALB severity (62.80%), AUDPC (723), and powdery mildew (27.11%). Consequently, seed yield declined from 2492.60 kg/ha to 1183.51 kg/ha, showing the critical role of early sowing in avoiding weather conditions conducive to disease development. Correlation analysis revealed a strong association between disease severity and meteorological parameters. ALB severity exhibited significant positive correlations with maximum temperature ( $r = 0.609$ ,  $p < 0.01$ ) and sunshine hours ( $r = 0.575$ ,  $p < 0.01$ ), and strong negative correlations with relative humidity ( $RH_{\max}$ :  $r = -0.753$ ,  $RH_{\min}$ :  $r = -0.775$ ). Kendall's tau non-parametric correlation analysis also supported these findings with similar trends. Likewise, powdery mildew severity was positively correlated with temperature and sunshine hours and negatively with relative humidity, indicating both diseases are favoured under warm, dry, and sunny conditions.

In vitro studies revealed that combined application of plant extracts [Agetox (AG) + Solatox (ST)], zinc chloride, and salicylic acid were most effective against *A. brassicae*. Agetox + Solatox recorded the highest mycelial growth inhibition (57.01%), while salicylic acid showed the lowest  $LC_{50}$  (4.96 mM), indicating strong antifungal efficacy. These eco-friendly treatments significantly reduced conidial production and mycelial width compared to untreated controls. Notably, AG+ST reduced conidial load by 9.53%, while salicylic acid achieved 61.01% reduction in mycelial width. Such treatments support sustainable management practices with reduced dependence on synthetic fungicides. Eco-friendly

treatments such as Agetox + Solatox and Solatox alone provided superior disease control (60–62%) over the untreated control under field condition. The highest seed yield (1991.75 kg/ha) was achieved in the AG+ST treatment, which also showed synergistic suppression of both diseases and a 25.7% yield enhancement compared to control.

Screening of mustard germplasm indicated significant varietal variation in response to *Alternaria* leaf blight disease severity. TM-433 showed the lowest disease severity (17.50%), followed by PM-25 while PM-25 and TM-433 exhibited the highest yields, signifying their potential for cultivation under disease-prone conditions. Integrated nutrient management (NP at RDF + 75% K + K spray twice) effectively reduced disease severity and improved seed yield (1703.53 and 1813.14 kg/ha, for the year 2023-24 and 2025 respectively), suggesting potassium's role in enhancing resistance. Overall, the study highlights that early sowing, integrated nutrient management, resistant varieties, and eco-friendly plant-based treatments are effective strategies for the sustainable management of *Alternaria* leaf blight and powdery mildew in mustard under changing climatic conditions in West Bengal specially in Red & Laterite Zone.

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### **Varietal Evaluation of Lentil Germplasms under Different Tillage and Soil Moisture Conservation Systems against Collar Rot Disease**

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Lentil (*Lens culinaris* Medik.), one of the cornerstones rabi pulse crops of the Indo-Gangetic plains, India, is cultivated through the quiet months of winter. Its identity brings glory through the enriched nutritional profile, the remarkable capacity to enhance soil fertility with biological nitrogen fixation and filling millions of stomachs through vegetarian diets. But beyond these natural phenomena, it weaves and maintains resilience inviting the upcoming sustainability in different agro-eco-systems. Unfortunately, despite all the benefits, this humble crop stands severely vulnerable amidst the invasion of pathogens, most importantly *Sclerotium rolfsii* causing collar rot which imposes a serious constraint towards optimum yield. The deadly infection becomes more severe under the shadow of changing climatic regimes and the increasing acceptability of resource conserving practices such as conservation agriculture, where the altered soil microenvironment inadvertently modifies the disease dynamics. The scientific investigation across diverse germplasms, against the drawback of promise and peril, runs to unravel the differential response of the examined genotypes under contrasting tillage and soil-moisture conservation systems, with a dual purpose of identifying promising genotypes against collar rot and enlightening how the systems reshaped the disease progression and terminal disease incidence. The work aimed at

bridging productivity and sustainability, guiding the lentil cultivation towards a more resilient future.

A set of 80 different germplasms was critically observed from sowing to harvesting against collar rot and blight complex under two different tillage conditions: Normal tillage and zero tillage with rice fallow for two consecutive seasons including 2023-24 and 2024-25. Similarly, during 2024-25, using a set of 25 selected genotypes, three different moisture conservation strategies including straw mulching applied, hydrogel applied and no moisture conserving conditions were applied to assess the comparative efficiency of each system against disease severity and the associated factors.

Under the normal tillage, during the previous season (2023-24), collar rot was prevalent with a moderate level of severity showing mean Percent Disease Incidence (PDI) of 23.56% and a standard deviation of 9.45, reflecting considerable fluctuation in disease response among the evaluated genotypes. Nearly 42.5% of the germplasms fell within the category of 10–20% disease incidence range, indicating differential levels of tolerance. As opposed to this, within the same cropping season, zero tillage exhibited a lower mean PDI of 20.79% with a more stable performance of the genotypes with SD 8.92 only. A larger proportion of germplasms (58.75%) exhibited disease incidence in the 10–20% range category under zero tillage, suggesting a general reduction in disease severity under this system. This reduction may be attributed to limited soil disturbance and changes in soil microclimate that potentially influence pathogen activity and host–pathogen interactions. Varietal evaluation across the two tillage systems identified several moderately resistant genotypes, notably NB-21-497, NB-21-90, and NB-21-199, which consistently exhibited lower disease incidence under both conventional and zero tillage conditions. However, a few genotypes showed increased susceptibility under zero tillage, highlighting that varietal responses to collar rot are influenced by tillage practices and agro-ecological conditions.

The next season (2024-25) was no exception in showing this trend of disease severity and stability. Under conventional tillage, the mean collar rot incidence increased slightly to 25.51% with a standard deviation of 8.13, and 28.75% of the germplasms fell within the 10–20% disease incidence category. Under zero tillage, the mean PDI was again lower at 22.44% with a standard deviation of 7.55, and 45% of the genotypes fell in the category of 10–20% PDI range. These observations further reinforce the potential of zero tillage in mitigating collar rot severity, possibly through improved soil structure, residue retention, and moderated soil temperature and moisture regimes. The same set of genotypes—NB-21-497, NB-21-90, and NB-21-199—maintained their moderate resistance across seasons and tillage systems, indicating stability in their disease response. Nevertheless, the differential performance of certain genotypes under zero tillage underscores the need for system-specific varietal selection.

Soil moisture conservation practices exerted a significant influence on disease development. Among the evaluated treatments, the application of straw mulching in the recommended dose resulted in the lowest collar rot incidence, followed by Pusa hydrogel application, while the untreated control recorded the highest disease severity level. The suppressive effect of straw mulching on collar rot may be attributed to its capacity to exert a

buffering effect on soil moisture and temperature, thereby altering the rhizospheric environment in a manner unfavorable for pathogen proliferation. However, a contrasting trend was observed for foliar blight severity. The highest percentage disease index was recorded under hydrogel application (37.44%), followed by straw mulching (33.81%), whereas the conventional moisture regime exhibited the lowest blight severity (33.39%). The gradual recording of SPAD values at different DAS levels from strong and weak genotypes against blight complex provided an indirect measurement of chlorophyll content and the observation confirmed an inverse relationship between blight severity and chlorophyll content.

Assessing the soil microbial population using the collected soil samples from different systems at 0,30, 60 and 110 DAS levels was carried out as indirect evidence of the contrasting responses of genotypes against collar rot disease under different tillage and moisture conserving strategies. Zero tillage with rice fallow consistently supported a more enriched population of soil fungi, bacteria, phosphate solubilizing bacteria and actinomycetes, as compared to the normal tillage, especially during the later stages of crop growth. Similarly, both hydrogel and straw mulching treatments recorded significantly higher microbial populations than the untreated control. Among the moisture conservation strategies, hydrogel application resulted in the highest fungal and bacterial populations at 30 and 60 days after sowing, while straw mulching also sustained robust microbial growth across all microbial groups. These results indicate that conservation-oriented practices not only influence disease dynamics but also enhance soil biological activity and overall soil health.

After the harvesting of the crop, the seed yield was also recorded for the three moisture conservation systems and straw mulching provided the highest yield and productivity, followed by hydrogel and the no moisture conservation system (untreated control) exhibited the poorest performance. This again established the reason why straw mulching could be the best system in an overall aspect combining the lowest collar rot disease severity, the intermediate blight severity and the highest yield.

Integrating all the observations, the study conclusively demonstrated that the integration of zero tillage with appropriate moisture conservation practices like straw mulching, can play a crucial role in reducing collar rot incidence in lentil along with enrich the soil microflora and enhancing the yield significantly. The identification of stable, disease-tolerant germplasms such as NB-21-497, NB-21-90, and NB-21-199 provides valuable material for breeding programs aimed at developing climate-resilient lentil varieties. Collectively, these findings offer practical insights for sustainable disease management and support the adoption of ecologically sound production systems in pulse-based agro-ecosystems under changing climatic scenarios.

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## Characterization of Important Fungal Pathogens of Ginger (*Zingiber officinale* Rosc.) with Special Reference to Epidemiology and Management

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Ginger (*Zingiber officinale* Rosc.), a valuable spice crop of tropical Asia, holds immense economic, medicinal, and industrial significance globally. As a rhizomatous perennial belonging to the family Zingiberaceae, West Bengal is a major contributor, producing an estimated 138.58 thousand tonnes from about 1.25 lakh hectares by 2025. However, ginger cultivation in this region is threatened by several fungal pathogens that lead to significant yield and quality losses, most notably during the monsoon season. This study, focused on the isolation, identification, epidemiological study, and management of ginger pathogens mainly two key fungal pathogens of ginger: *Phyllosticta zingiberi* and *Chaetomium* sp. These pathogens, although reported in scattered studies, have remained underexplored within the agro-climatic conditions of North Bengal as well as South Bengal. The research was designed to fill this knowledge gaps.

Field surveys were conducted from July to November 2024 across ginger-growing districts in West Bengal Coochbehar, Alipurduar, and Nadia. Several ginger cultivars, including Gorubathan, Moran Ada, Himgiri, and Suravi, were observed for disease incidence. Disease severity was quantified using established scales like the Saari–Prescott scale (1975) and the Mayee and Datar scale (1986). Percent Disease Index (PDI) and Area Under Disease Progress Curve (AUDPC) values were calculated to determine varietal resistance or susceptibility. Isolates were morphologically and micro-metrically characterized using standard medias (PDA, MEA, OMA etc.) and subjected to nutrient-based optimization studies (Das *et al.*, 2021).

In the laboratory, pathogens were isolated and cultured on ten different medias including Potato Dextrose Agar (PDA), Malt Extract Agar (MEA), and Oatmeal Agar (OMA). Environmental factors such as pH, carbon and nitrogen sources, and temperature regimes were also varied to determine optimal conditions for fungal growth. Both pathogens showed best mycelia growth between 25–30°C and at pH 6–7. A strong negative correlation was observed between disease incidence and maximum temperature (T<sub>max</sub>). *In vitro* fungicidal efficacy studies were conducted using the poisoned food technique. Among the tested fungicides, systemic chemicals such as Carbendazim and Propiconazole achieved over 90% inhibition of fungal growth, whereas contact fungicides like copper oxychloride was moderately effective. Biocontrol agents, namely *Trichoderma harzianum* and *T. viride*, demonstrated significant antagonistic effects, inhibiting more than 70% of pathogen growth

in dual culture assays. These results were validated *in vivo* by using several contact and systemic fungicides led to significant reductions in disease severity across all tested cultivars. This study contributes significantly to the scientific understanding of fungal disease dynamics in ginger under Eastern Indian conditions. The research identifies critical factors for disease development, confirms pathogenic variability, and establishes effective control measures and thus, this work forms a strong foundation for long-term ginger crop protection strategies that are eco-friendly, economically viable, and regionally adaptable.

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## **Study on Taxonomy of Chalcididae (Hymenoptera: Chalcidoidea) of New Alluvial Zone in West Bengal**

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The present study assessed the trapping efficiency among the three sampling gadgets, which included the sweep net, the yellow pan trap at ground level, and the Malaise trap in the horticultural crop ecosystem. The study aimed to document an updated West Bengal checklist along with preparing the world (dichotomous) key of subfamily Dirhininae Ashmead, 1904, and genus *Eniacomorpha* Girault, 1915. The taxonomic study of the reported specimens from the study area was also fulfilled.

Specimens were collected from multiple locations across six districts of the New Alluvial Zone of West Bengal. The selected sites included Naopara village in East Bardhaman; Hooghly Krishi Vigyan Kendra in Hooghly; Horticultural Farm, Mandouri, and District Seed Farm (AB block, BCKV) in Nadia; and Karna Madhabpur village, Khardah, in North 24 Parganas. Additional specimens were obtained from Kaliachak in Malda district and from Umarpur and Bazarsau in Murshidabad district for taxonomic examination. A field experiment to assess trapping efficiency was conducted at the Mandouri Horticultural Farm, Nadia district, from October 2024 to March 2025. Standardized sampling protocols were followed, consisting of 100 sweep net strokes between 9:30 and 11:30 am, deployment of 25 yellow pan traps for 24 hours, and installation of a Malaise trap for one week (Mukundan and Rajmohana, 2018). Yellow pan traps were arranged in a quincunx pattern in litchi orchards, while in crops with less dense canopy, they were placed near the plant base, maintaining a minimum spacing of one meter between traps. Live specimens collected by sweeping along with plant debris in ziplocked plastic pouches were freeze-dried for 24 hours, followed by chalcidid segregation and debris elimination in a petri plate containing 70% alcohol. They were eventually dried and immediately card-mounted. If collected in 70% alcohol, the collection after debris removal and segregation of non-chalcidid specimens was likewise

card-mounted. The samples obtained from yellow pan traps were carefully filtered through a fine tea sieve and put in clean water in a petri plate to wash off the detergent and salt deposition over the trapped specimens, which otherwise left a white cast on drying, followed by air-drying and card mounting. In the case of the Malaise trap, specimens collected in the alcohol-containing collection jar were similarly segregated, air-dried, and eventually card-mounted. For card mounting, small triangle-shaped cuts were made out of stiff white paper. Its apex was slightly folded downwards to increase the surface of contact, and a minute amount of white glue (water soluble) was placed. With a fine brush (size 00 or 000), the specimen was picked up by touching its mesopleuron and gently positioned on a drop of glue with its head facing towards the far end and body angled 45° to the card. The card-mounted specimens were preserved in insect boxes with naphthalene balls wrapped in tissue paper pinned at a corner to prevent any insect or fungal attack. The insect boxes were checked periodically for any fungal growth and stored in a dry place. The card-mounted dried specimens were identified and photographed under a Magnus MSZ-Bi stereo zoom microscope. The morphometric analysis was done under Olympus SZX7. The species were identified using keys by Bouček & Narendran (1981), Narendran (1989), Narendran & Achterberg (2016), Schmitz (1946), and Masi (1947). The Shapiro-Wilk normality test was applied to the data to find whether the data followed a normal distribution. As the data showed normal distribution with the P-value > 0.05, parametric tests were applied. The statistical test one-way ANOVA was employed to check any significant difference in the trapping efficiency. It was followed by a post-hoc Fisher's Least Significant Difference (LSD) test to compare all possible pairs of group means after a significant F-test result. The level of significance was considered at 5% for computing all critical difference values. All the statistical analyses were made in Microsoft Excel 2021 version.

Experimental results revealed that the mean number of chalcidid wasps caught per day by the yellow pan trap was 10.167, followed by the sweep net and the Malaise trap, which were 8.333 and 2.833, respectively. The Malaise trap was found to be inferior among the three, with both the sweep net and yellow pan trap being statistically at par in quantitative estimation. Although the yellow pan trap was better in qualitative (more diverse genera trapped) estimation in the horticultural crop ecosystem. The documentation of the first updated Chalcididae checklist of West Bengal was made with 49 species in 15 genera under 5 subfamilies except for the subfamilies Chalcidinae, Cratocentrinae, and Smicromorphinae. The world (dichotomous) keys of subfamily Dirhininae Ashmead, 1904, and genus *Eniacomorpha* Girault, 1915, were outlined. In total, morphometric studies and images of 10 species from 5 genera falling under three subfamilies were presented along with a redescription of *Eniacomorpha ugandensis* (Masi). During the study, *Eniacomorpha ugandensis* (Masi) was first reported from India. Furthermore, newly recorded species from West Bengal included *Antrocephalus lugubris* (Masi), *Antrocephalus maculipennis* Cameron, and *Kriechbaumerella nepalensis*. Roy & Farooqi from the present study.

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## Development of Isothermal Nucleic Acid Amplification Assay for Detection of Melon Fly, *Zeugodacus cucurbitae* (Coquillett) (Diptera: Tephritidae)

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Fruit flies (Diptera: Tephritidae) comprise a highly diverse group, with nearly 200 economically important species. Among these, the melon fly, *Zeugodacus cucurbitae* (Coquillett, 1899), is a destructive, polyphagous pest capable of inflicting up to 100% yield loss. Due to its impact and the enforcement of strict international quarantine, rapid and accurate identification is essential for effective pest management and decision-making. Morphological diagnosis is particularly challenging in immature stages, while DNA barcoding offers a precise molecular alternative but depends on high-quality DNA, conventional extraction methods such as CTAB and phenol–chloroform are time-consuming and infrastructure-dependent. Commercial kits also remain too costly for large-scale or resource-limited applications. To address this limitation, eleven rapid and low-cost DNA extraction protocols were assessed for *Z. cucurbitae*. Of these, four (Tween 20 + NaOH, PBS, TE buffer, and Chelex + Proteinase K) produced DNA of sufficient quality for molecular applications, confirmed through successful amplification of the mitochondrial COI gene with primers LCO1490/HCO2198. Furthermore, a simple template-based Loop-Mediated Isothermal Amplification (LAMP) assay targeting the COI gene was developed to overcome the limitations of conventional PCR and barcoding. The Melon fly-LAMP assay enabled detection of all life stages of *Z. cucurbitae* within 40 minutes at 60 °C, with high specificity validated against closely related non-target species, *Z. tau* Walker, 1849; *Bactrocera dorsalis* (Hendel, 1912); *B. divenderi* Maneesh, Hancock & Prabhakar, 2022; *B. zonata* (Saunders, 1842); and *B. correcta* (Bezzi, 1916). The assay displayed high sensitivity with detection limits of  $1 \times 10^{-12}$  ng/ $\mu$ l for genomic DNA) and  $1 \times 10^{-16}$  ng/ $\mu$ l for plasmid DNA. Among tested template preparations, ddH<sub>2</sub>O proved most suitable with LAMP assay for field use, enabling successful validation across laboratory, field, and market samples, as well as specimens collected from six regions of India. Overall, the integration of simplified DNA extraction with Melon fly-LAMP assay provides a rapid, low-cost, sensitive, accurate, and portable diagnostic platform for surveillance, quarantine inspection, and biosecurity interventions, thereby supporting sustainable agricultural production.

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***Shashya Suraksha Best Ph.D Thesis  
Competition Award***

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## Assessment of Leaf Curl Infection Risk in Relation to Host–Vector Interaction: Aiming at the Development of Strategic Management Options

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Chilli leaf curl disease, caused by Chilli leaf curl virus (ChiLCV) and transmitted by the whitefly *Bemisia tabaci*, is a major constraint to chilli production due to diagnostic confusion with symptomatically similar damage caused by mites and thrips. This study presents an integrated, field-deployable disease management framework that combines early detection, precise molecular diagnostics, and epidemiologically optimized intervention strategies. Non-invasive imaging approaches were developed for early and accurate detection, where thermal infrared imaging enabled pre-symptomatic ChiLCV detection under controlled conditions with 74.7% accuracy using zero-shot learning and automated SAM-based canopy segmentation, capturing host–pathogen interactions associated with altered stomatal conductance and transpiration. Although highly sensitive, microclimatic variability limits field deployment of thermal imaging, positioning it for seedling certification and protected production systems. For field surveillance, two complementary RGB-based systems were established. The lightweight SCA-MobiPlant classifier, integrating coordinated attention with MobileNetV3-Small, achieved 99.64% accuracy at 89 FPS using only 0.68 million parameters, reliably discriminating healthy, mite-affected, and virus-infected plants, while a semi-supervised annotation strategy reduced expert labeling effort by 30–50%. An advanced YOLOv9t-DyE + MobileSAM framework further enabled real-time detection, symptom discrimination, and pixel-level disease severity estimation, demonstrating robust field performance (POD 0.88, CSI 0.79) and a 12.15-fold reduction in assessment time. Both imaging systems were deployed as Android applications to support on-site diagnosis and disease incidence estimation. In parallel, a rapid point-of-care molecular diagnostic was developed using an RPA–CRISPR/Cas12a platform, overcoming PCR cross-reactivity and ELISA limitations and enabling specific ChiLCV detection from crude leaf extracts within one hour, including pre-symptomatic infections, with optimized lateral-flow interpretation supported by quantitative threshold modeling. Epidemiological modeling further identified immigration of viruliferous whiteflies as the primary epidemic driver, with host succulence governing transmission efficiency, and field validation revealed a critical intervention window at 3–4 weeks post-transplantation during which physical vector barriers maximized yield gains ( $\approx 3.7 \text{ t ha}^{-1}$ ). Together, this framework integrates imaging, molecular diagnostics, and epidemiological insights into a practical, chemical-free strategy for managing ChiLCV and other vector-borne plant diseases.

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## **Influence of Edapho-Climatic Factors on Survival and Pathogenicity of *Ralstonia solanacearum* and the Biochemical Basis of Resistance in Brinjal against Bacterial Wilt**

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The bacterial wilt incited by *Ralstonia solanacearum* is a menace to vegetable growing farmers of West Bengal and have remained uncontrolled due to its diverse genetic and adaptive attributes. *R. solanacearum* exhibits a great degree of both phenotypic and genotypic diversity. Being a very “environmentally conscious” microorganism capable of actively multiplying under nutrient-adequate conditions and surviving in natural environments, population dynamics of *R. solanacearum* is strongly influenced by various environmental factors. Breeding approaches for the development of resistant cultivars having broad spectrum-resistance to diverse strains of *Ralstonia solanacearum* species complex (RSSC) is an important part of a composite strategy for managing this dreaded pathogen in bacterial wilt conducive areas. Information regarding the interaction between host pathogen and environment is important for better understanding of disease development and for prediction of future disease outbreak. The complex interaction of soil environmental factors, crops and their rhizo-deposition, soil physico-chemical and biological properties not only trigger or modulate metabolic pathways of this bacterial pathogen but affect the growth rate, survival, colonization in crop-rhizosphere ecosystem and host interaction. The present investigation is focused around thorough investigation on the underlying mechanisms involved in brinjal – *R. solanacearum* interaction among the resistant and susceptible varieties and effect of soil physico-chemical properties, textural classes, influence of temperature, moisture, pH and their interaction on growth and survivability of *R. solanacearum*.

The survey work on vascular bacterial wilt (VBW) disease was conducted at different parts of Nadia district and maximum VBW disease incidence was observed in Simurali (37.67 %) followed Madanpur (36.20 %) and Kasimpur (25.00 %) during 2018-19 whereas during 2019-20 maximum VBW incidence was noticed in Madanpur (39.00 %) followed by Simurali (38.25 %) and Kasimpur (31.17 %). Rice, cabbage and cauliflower as previous crop reduced bacterial wilt incidence. It was observed that the VBW incidence was severe during July to November with disease ranging between 22.00 - 40.50 % during 2018 and 25.00-41.50 % during 2019. Seven weed plants were found to be symptomless carrier and tested positive for *R. solanacearum* and these were *Ageratum conyzoides*, *Amaranthus spinosus*, *Croton sparsiflorus*, *Physalis minima*, *Solanum nigrum*, *Solanum indicum* *Portulaca oleraceae*.

The optimum temperature for growth of *R. solanacearum* was between 27-35°C. NaCl concentration of 0.0% to 0.5% and pH 5-7 was found to be the optimum for the growth of *R. solanacearum*. Among the five different soil organic amendments neem cake and vermicompost were effective in reducing VBW of brinjal. The disease incidence was above 75 % in Kalimpong soil (82.50 %: Hill soil) and Shekhampur soil (77.50 %: Red and lateritic soil) whereas the disease incidence was below 50.00% in Kakdwip soil (coastal saline zone). Under non-sterile condition the longer survivability was observed under the soil of Kalimpong of Darjeeling district. The survivability of *R. solanacearum* under non-sterile conditions was significantly negatively correlated with pH, K<sub>2</sub>O, calcium, copper and manganese. The combination of temperature 27°- 30° C and 70% FC moisture facilitated the survivability of *R. solanacearum* in both non-sterile and sterile soil. The temperatures between 30 to 35°C and 70% FC soil moisture were found to be congenial for pathogenicity of *R. solanacearum* in brinjal host. The VBW disease incidence was significantly high when the transplanting of brinjal seedlings were done during May to July months. However, disease incidence was recorded below 10% during 2018-19, when the transplanting was carried out in first week of both November (7.77%) and January (6.94%), whereas the disease incidence during 2019-20 was below 5% when seedlings were transplanted in the third week of December (2.22%) and last week of January (2.22%). Soil temperature and moisture were found to be the most important estimators for predicting VBW disease incidence in brinjal.

Two cultivars, namely Utkal Madhuri and Utkal Anusree were categorised as resistant, one variety (Utkal Jyoti) as moderately resistant, one variety (Utkal Keshari) as moderately susceptible and two cultivars, namely Gauria and Muktakeshi highly susceptible. The present findings indicated that, higher ratio of large and small vessels in both stem and roots could be considered as promising criteria of selection of germplasm in developing a robust cultivar of brinjal that is resistant and/or tolerant against bacterial wilt disease. The present investigation indicated that the movement and spread of the pathogen in the vascular system of the resistant cultivar was slower than that of the susceptible cultivar.

In the present study, initial H<sub>2</sub>O<sub>2</sub> production followed by POD and PAL activity and resultant increased phenol content might be the important parameters related to tolerance of brinjal plants towards *R. solanacearum*. Transcriptome of the resistant and susceptible plants were sequenced with and without *R. solanacearum* inoculation and GO biological process ontology was performed for the same. From the transcriptome sequencing and GO biological process ontology, in R-I vs. S-I combination, 227 unigenes were upregulated and 344 unigenes were downregulated with more than 2 logFC diversion. Comparison of upregulated and downregulated unigenes of resistant and susceptible varieties challenged with *R. solanacearum* indicated significant change in expression of several defense related or immune-related genes and after validation, these genes may be utilized for development or selection of tolerant germplasm of brinjal towards *R. solanacearum*.

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## Machine Vision Based Site Specific Spraying Robot for Protected Cultivation

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Cultivation of vegetables in protected cultivation offers controlled environmental conditions that enhance crop productivity and quality; however, these favourable microclimates can also promote the rapid development and spread of pests and diseases. Tomato, a high-value vegetable crop widely grown under greenhouse conditions, is particularly vulnerable to fungal infections, among which early blight causes substantial yield losses. Conventional disease diagnostic methods based on visual scouting and laboratory analyses are labour-intensive, time-consuming, and impractical for large-scale or real-time crop management. Moreover, greenhouse pest management commonly relies on blanket pesticide applications, leading to excessive chemical use and increased exposure of operators during spraying, thereby posing serious occupational health risks. In this context, the present study was aimed to develop a machine vision-based, site-specific spraying robot for precise detection and targeted management of early blight disease in tomato under protected cultivation. A lightweight object detection model, YOLOv10n, was trained using a rigorously validated dataset comprising 6,068 images of healthy and early blight-infected tomato leaves. The presence of the causal pathogen, *Alternaria alternata*, was confirmed through morphological characterization and molecular validation using internal transcribed spacer (ITS) sequence analysis. The trained YOLOv10n model was subsequently integrated into a machine vision-based site-specific spraying system. In addition, six convolutional neural network (CNN) models including MobileNetV2, DenseNet121, InceptionV3, VGG19, NASNetMobile, and a custom model developed from scratch, were trained and validated for disease severity classification, providing future scope for variable-rate chemical application. Experimental investigations using a customized test setup were conducted to optimize key operational parameters, including camera scanning speed, vehicle forward speed, spray nozzle size, nozzle spacing, number of nozzles, and operating pressure. Three levels of linear scanning speeds (9.7, 12.3, and 15.5 cm.s<sup>-1</sup>) and vehicle forward speeds (0.35, 0.50, and 0.65 km.h<sup>-1</sup>) were evaluated to assess their effects on disease detection accuracy. Three levels of nozzle sizes (0.19, 0.57 and 1.19 l.min<sup>-1</sup>) based on international standard, operating pressures (2, 3 and 4 kg.cm<sup>-2</sup>) and nozzle spacings (35, 45 and 55 cm), were evaluated at two levels of canopy position (in line with nozzle axis and centrally between two nozzle axes) to analyze their effect on spray deposition characteristics. Based on the optimized parameters, a track-type robotic sprayer integrated with a linear camera scanning mechanism and an embedded control-based spraying system was developed. The tracked configuration was selected

considering greenhouse soil conditions and agronomic requirements, while skid-type steering was adopted to enable zero-radius turning in confined spaces. The robotic platform was powered by four DC motors controlled via an Arduino Uno microcontroller and operated using a Flysky FS-CT6B remote controller. Vertical linear motion of the camera was achieved using a stepper motor controlled by an Arduino Mega microcontroller. The embedded control system comprised a Jetson Nano, Intel RealSense D435 camera, Arduino Mega, stepper motor, motor driver, USB-to-TTL converter, buck converter, relay module, solenoid valves, spray nozzles, pump, and a 12 V Li-Po battery, enabling real-time disease detection and site-specific pesticide application through selective nozzle actuation based on camera position. The developed robotic sprayer was evaluated under greenhouse conditions at optimized operating parameters and compared with a conventional knapsack sprayer. The object detection model YOLOv10n employed in this study achieved very high precision (0.947), recall (0.953), and mAP scores (0.935-0.985), indicating its strong capability to accurately distinguish diseased leaves from healthy foliage. Among the CNN models evaluated for disease severity classification, fine-tuned DenseNet121 consistently outperformed other architectures by achieving the highest classification accuracy of 99.61 percent. A hollow cone nozzle with flow rate of 0.58 l.min<sup>-1</sup> at operating pressure of 3 kg.cm<sup>-2</sup> and inter-nozzle spacing of 45 cm provided spray characteristics within recommended limits for foliar fungicide application and were thus selected for sprayer design. A robotic target sprayer of dimensions 87 cm × 70 cm (length × width), power requirement of 170 W-h with quad-core ARM Cortex-A57 processor was developed. The developed robotic target spraying system achieved a detection actuation accuracy of 88.77 percent, an effective field capacity of 0.021 ha.h<sup>-1</sup> and field efficiency of 80.77 percent. Site-specific spraying in tomato with the use of developed sprayer resulted in a pesticide saving of 78.30% compared to conventional knapsack sprayer, highlighting its potential for sustainable and economical disease management. Overall, the developed machine vision based site-specific spraying robot exhibited considerable potential for precision disease management in greenhouse tomato production by enhancing spray accuracy, minimizing pesticide usage, and improving operator safety.

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## Identification and Characterization of *Brassica juncea* L. (Czern & Coss) Genotypes for Different Mechanisms of Resistance to Aphid, *Lipaphis erysimi* (Kaltenbach)

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The study conducted to elucidate physico-morphological, biochemical, nutritional, and enzymatic factors governing resistance and susceptibility of Indian mustard to mustard aphid. Mustard aphid (*Lipaphis erysimi*) is a major biotic constraint limiting productivity of *B. juncea*, and host plant resistance remains a key component of sustainable aphid management. Significant genotypic variation was observed among the tested *B. juncea* genotypes for diverse phenological, morphological, and yield-attributing traits. Morphological traits act as primary cues for aphid orientation and establishment. Phenotypic traits such as point to first branch, siliqua length, and total siliquae per plant were significantly and negatively associated, while point to first siliqua on the main shoot and seeds per siliqua were positively associated with aphid resistance index. Correlation and path coefficient analyses revealed that aphid number, aphid population index, and aphid damage index were significantly and positively interrelated and indirectly contributed to variation in aphid resistance index among genotypes. Plant height was greater in PDZ 6, which showed lower aphid infestation compared to other genotypes. Higher numbers of branches were recorded in RBJ 11, RBJ 77, RBJ 49, NPJ 161, NRCHB 101, and Rohini, which harboured comparatively fewer aphids. The highest aphid population was recorded on bunchy mutant IC 355399, whereas Pusa Tarak with appressed siliquae supported intermediate aphid populations. Leaf and stem colour did not influence aphid incidence at early infestation stages. Flower colour showed variable effects; genotype GP 454 with creamish flowers had lower aphid infestation, whereas IC 355399 with dark yellow flowers showed higher infestation under natural conditions. Closely oriented siliquae on the main shoot, as observed in bunchy mutant IC 355399, favoured aphid colonization. Longer siliqua length positively influenced aphid population, with Pusa 119-1-3 harbouring higher aphid numbers than Pusa 119-1-1 and Pusa 119-1-2.

Under natural infestation conditions, genotypes RBJ 11, RBJ 77, RBJ 49, NPJ 161, PDZ 6, Pusa 119-1-3, Pusa 119-1-1-2, PM 30, PM 25, TN 3, GP 454, RLC 3, and Kranti recorded significantly lower aphid populations, while Rohini, IC 355399, EC 61-9-2-2-2, RP 11-2-1-3-1, EC 62-46-1, and NRCHB 101 were highly susceptible. Under artificial infestation, RBJ 11, NPJ 161, PDZ 6, PM 30, PM 25, RLC 3, and Kranti remained relatively resistant, whereas IC 355399, YSG, and TS 18-5124 were highly susceptible. Significant differences were observed in the developmental period, reproductive period, fecundity, and

survival of *L. erysimi* on different plant parts (leaves, buds, immature siliquae, and grain-filled siliquae). Across plant parts, aphids exhibited prolonged developmental periods and reduced fecundity and survival on Kranti, RLC 3, NPJ 50, GP 454, Rohini, and IC 355399, indicating antibiosis-based resistance. Leaves of RLC 3, IC 355399, Rohini, GP 454, NPJ 50, TS 18-5124, and Kranti contained higher levels of defense-related biochemicals, adversely affecting aphid reproductive performance and survival, and thus serve as potential selection indices for resistance.

Preference studies revealed that RLC 3, Kranti, and IC 355399 were least preferred by aphids, whereas leaves and buds of PM 30, PM 29, and RH 749 were more preferred. Genotypes PM 30, RH 749, PDZ 6, Pusa 119-1-3, Pusa 119-1-1, and Kranti showed reduced aphid multiplication rates and population build-up, along with higher chlorophyll and carotenoid contents, indicating tolerance mechanisms. Prolonged nymphal period on EC 62-46-1, Pusa Tarak, PM 30, RH 749, RP 7-3-2-21, PDZM 31, NRCHB 101, YSG, TS 18-5124, TN 3, and RP 11-2-1-3-1 further suggested antibiosis effects.

Biochemical analyses revealed significant differences in constitutive and induced defense compounds across genotypes and plant parts under healthy and aphid-infested conditions. Aphid infestation resulted in increased starch, sugars, proteins, phenols, antioxidants, FRAP, tannins, defense enzyme activity, and macronutrient content, while glucosinolates and photosynthetic pigments declined. Genotypes RLC 3 and Kranti, characterized by low sugar and lipid contents and higher protein, starch, phenol, antioxidant, FRAP, and tannin levels, exhibited enhanced tolerance. In contrast, genotypes with higher lipid content and lower phenolics (RBJ 11, RBJ 77, RBJ 49, NPJ 161, PDZ 6, EC 62-46-1, and Pusa 119-1-3) were more preferred by aphids. Statistical analyses demonstrated that total antioxidants and tannins together explained 63.1% variation in aphid fecundity on buds, while ascorbate peroxidase alone accounted for 55.0% variation in aphid survival. Nitrogen content significantly influenced aphid fecundity, survival, and developmental period across plant parts. On immature and grain-filled siliquae, FRAP, tannins, starch, proteins, and nitrogen collectively explained major variation in aphid development, fecundity, and survival, highlighting the integrated role of nutritional and defensive traits.

The present investigation demonstrated that resistance and susceptibility of *B. juncea* genotypes to mustard aphid, *L. erysimi*, are governed by a complex interplay of physico-morphological traits, constitutive and induced biochemical defenses, enzymatic activities, and macronutrient composition. Significant genotypic variation was recorded in phenological and yield-attributing traits, which influenced aphid orientation, establishment, and population build-up. Morphological characters such as plant height, branching pattern, siliqua orientation, and siliqua length played important roles in determining aphid preference and colonization.

Aphid performance parameters, including developmental period, fecundity, and survival, varied significantly across genotypes and plant parts, confirming the presence of both antibiosis and antixenosis mechanisms. Genotypes such as RLC 3, Kranti, GP 454, NPJ 50, Rohini, IC 355399, and TS 18-5124 exhibited enhanced resistance through prolonged aphid developmental periods, reduced fecundity, and lower survival. Preference studies

further revealed differential utilization of leaves, buds, and siliquae, emphasizing the role of tissue-specific defense expression. Biochemical analyses established that higher levels of total phenols, tannins, antioxidants, FRAP, proteins, and starch, coupled with lower sugar and lipid contents, were associated with reduced aphid fitness. Aphid infestation induced significant up-regulation of defense-related enzymes and metabolites, while photosynthetic pigments and glucosinolates generally declined. Correlation and path coefficient analyses identified key biochemical and enzymatic traits-particularly tannins, antioxidants, FRAP, ascorbate peroxidase, and nitrogen content-as major determinants of aphid fecundity, survival, and development.

Overall, the study confirms that aphid resistance in *B. juncea* is a multicomponent trait involving both direct and induced defense mechanisms. The identified resistant genotypes represent valuable genetic resources for incorporation into mustard breeding programs aimed at developing aphid-tolerant, high-yielding cultivars, thereby reducing reliance on chemical insecticides.

## *Late Arrivals*

**ILT-25**

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### **Lightweight Deep Learning Models for Crop Stress Detection**

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Agriculture plays a very important role in ensuring food security, rural livelihoods, and economic stability. Specifically in developing countries like India, it is very crucial. It is very necessary to have an intelligent, scalable, and field-deployable solution for crop disease detection in precision agriculture. Due to diseases and stresses, globally, 20 – 40% of crop yield is lost. This affects significantly small and marginal farmers. Traditional visual inspection and expert-based diagnosis are more time-consuming, and it is very difficult to scale in large agricultural regions. It is also more difficult when field conditions are complex, which include illumination variation, complex background, and similar symptoms across diseases. This talk presents the design and evaluation of a lightweight deep learning framework for crop disease classification under real-world farming environments. It addresses major challenges such as background noise removal, domain shift between laboratory and field datasets, limited annotated Indian datasets, and deployment constraints on low-cost devices. The work explores state-of-the-art image processing and deep learning techniques for crop disease classification and proposes lightweight CNN-based models that improve efficiency, accuracy, and interpretability. A hybrid approach was introduced that combines handcrafted and deep features to improve rice disease classification. To focus on relevant disease-affected areas, a crop segmentation algorithm was also used. Additionally, a hybrid CNN, which is integrated with an autoencoder is developed. The main objective for this is to highlight stress regions in diseased leaves. It supports effective biotic stress identification. For efficient large-scale classification, a lightweight CNN model is designed to achieve high accuracy across multiple plant species. Maintaining low computational complexity remains the highest priority. The framework also combines explainable AI techniques such as Grad-CAM, Grad-CAM++, and LIME. These are used to increase model transparency and interpretability. A non-destructive image-based approach is presented for detecting abiotic stress, specifically nitrogen deficiency in rice crops. An augmentation strategy is introduced to improve robustness under real-field conditions. The framework gives priorities to efficiency, interpretability, and deployability. It also offers a practical solution for precision agriculture. It facilitates early intervention and sustainable crop management.

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## Effect of Climate Variability on the Development, Survival and Outbreaks of *Leucinodes orbonalis* in Brinjal

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Extreme weather patterns driven by climate change strongly affect the biology and infestation severity of the brinjal shoot and fruit borer, *Leucinodes orbonalis*, a major pest of brinjal (*Solanum melongena*). Its life cycle includes egg (3–5 days), larvae (10–20 days), pupae (7–10 days), and adult (10–15 days), but durations can fluctuate with temperature, humidity, and host plant quality, resulting in total development of 30–50 days. Rising temperatures accelerate development, shorten generation time, and increase reproductive output, producing multiple overlapping generations and intensified infestations. Mild winters enhance pupal survival and facilitate geographic expansion, while drought and irregular rainfall alter host plant physiology, reducing defenses and affecting larval feeding. Heavy rainfall can temporarily reduce early-stage populations but often triggers secondary outbreaks. Extreme weather also disrupts natural enemies, further exacerbating pest pressure. Climate-resilient strategies, including resistant varieties, predictive forecasting, and integrated pest management, are critical to maintain sustainable brinjal production under changing climatic conditions.

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## Biology and Predatory Potential of *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) on *Aphis gossypii* (Glover) and *Phenacoccus solenopsis* (Tinsley) in Laboratory Conditions

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A laboratory investigation was conducted to evaluate the predatory potential of the green lacewing, *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae), against major

sucking pests, *Aphis gossypii* (Glover) and *Phenacoccus solenopsis* (Tinsley), under controlled conditions ( $25 \pm 5^\circ\text{C}$  and  $65 \pm 5\%$  RH). The experiment was laid out in a Completely Randomized Design with three replications, assessing stage wise and total prey consumption of first, second and third instar larvae. Results revealed that predatory efficiency increased significantly with larval advancement. The first instar larvae exhibited limited feeding capacity and were unable to attack adult mealybugs. In contrast, the second and third instars demonstrated markedly higher voracity across all prey stages. Maximum total prey consumption during the entire larval period was recorded on first instar nymphs of *P. solenopsis* ( $893.66 \pm 13.73$  individuals), followed by eggs of *Corcyra cephalonica* ( $724.33 \pm 24.67$ ) and nymphs of *A. gossypii* ( $495.33 \pm 5.81$ ). Minimum predation was observed on adult *P. solenopsis* ( $63.66 \pm 10.80$ ). The third instar contributed the highest proportion of total predation, highlighting its critical role in prey suppression. Variations in predatory performance among prey stages were attributed to differences in prey size, mobility and defensive characteristics such as wax coating. The findings demonstrate that *C. carnea* larvae, particularly the second and third instars, possess strong predatory potential against early instars of mealybugs and aphids. Therefore, strategic release of later larval instars could enhance biological control efficiency and support sustainable integrated pest management programs.

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## Diet-Mediated Modulation of Reproductive Fitness in Green Lacewing, *Chrysoperla carnea* (Stephens): Implications for Sustainable Mass Production and Biological Control

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Reproductive efficiency of biological control agents is a critical determinant of their success in sustainable pest management programs. The present study evaluated the influence of larval diet on the reproductive performance of the green lacewing, *Chrysoperla carnea* (Stephens), under controlled laboratory conditions ( $25 \pm 5^\circ\text{C}$ ;  $65 \pm 5\%$  RH). Seven larval diets comprising eggs of *Corcyra cephalonica*, nymphs and adults of *Aphis gossypii* and different instars of *Phenacoccus solenopsis* were assessed in a Completely Randomized, Design with three replications. Larval nutrition exerted a significant effect ( $p < 0.05$ ) on key reproductive parameters including pre-oviposition, oviposition and post oviposition periods, adult longevity, sex ratio and fecundity. Larvae reared on eggs of *C. cephalonica* exhibited superior reproductive performance, recording the shortest pre-oviposition period ( $2.87 \pm 0.24$  days),

extended oviposition duration ( $29.20 \pm 2.65$  days), highest female longevity ( $38.66 \pm 0.46$  days) and maximum fecundity ( $447.33 \pm 21.71$  eggs/female). Among natural prey, adults of *A. gossypii* supported comparable reproductive output ( $415.73 \pm 18.45$  eggs/female). In contrast, feeding on first instar *P. solenopsis* significantly reduced fecundity ( $313.40 \pm 10.10$  eggs/female) and adult longevity. The findings demonstrate that larval diet quality directly regulates reproductive fitness in *C. carnea*. Optimizing larval nutrition can substantially enhance mass rearing efficiency and augment field level biocontrol efficacy, thereby reinforcing green and sustainable Integrated Pest Management (IPM) strategies.

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## Morphological Characterization and Taxonomic Study of *Thrips florum* (Thysanoptera: Thripidae) Infesting *Gladiolus grandiflorus*

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*Gladiolus grandiflorus* is a commercially important ornamental crop valued for its vibrant floral spikes and premium status in the cut flower industry; however, its productivity is frequently limited by infestations of sucking pests, particularly thrips, which impair plant vigor and compromise floral quality. Despite the economic importance of gladiolus, detailed taxonomic documentation of associated thrips species remains inadequate in many production systems. The present study aimed to characterize and confirm the identity of *Thrips florum* (Thysanoptera: Thripidae) infesting gladiolus through detailed morphological examination and diagnostic evaluation. Specimens were collected from infested fields and analyzed using standard taxonomic keys, focusing on antennal segmentation, sensoria pattern, wing venation, setal arrangement, and abdominal chaetotaxy. Infestation symptoms included epidermal cell laceration, chlorophyll disruption leading to silvery streaking, necrosis, and reduced photosynthetic efficiency, along with floral deformation and discoloration at advanced stages. Accurate identification of the species provides a scientific basis for targeted monitoring and sustainable pest management strategies.

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## Comparative Evaluation of Bio-rational Pesticides against Major Sucking Insect Pests of *Gladiolus grandiflorus*

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*Gladiolus grandiflorus* L., a high-value ornamental crop, is frequently challenged by infestations of major sucking insect pests, particularly thrips and aphids, which adversely affect floral quality and economic returns under field conditions. Sustainable management approaches are therefore essential to minimize chemical dependency while maintaining effective pest suppression. The present investigation was conducted at the Faculty of Horticulture, SKUAST-K, to evaluate selected bio-rational insecticides against sucking pests under field conditions. Treatments included *Lecanicillium lecanii* ( $1 \times 10^8$  CFU/g), *Isaria fumosorosea* ( $1 \times 10^8$  CFU/g), neem oil (1%), neem seed kernel extract (5%), and Tolfenpyrad 15EC (0.15%) as the standard chemical check. Among the bio-rational treatments, *L. lecanii* demonstrated superior efficacy, significantly reducing thrips and aphid populations compared to other bio-agents. Although Tolfenpyrad 15 EC recorded the highest overall pest suppression, *L. lecanii* emerged as a promising eco-friendly alternative for sustainable sucking pest management in gladiolus.

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## Eco-Friendly and Chemical Approaches for the Management of Major Insect Pests in Okra

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Okra production is constrained by insect pests, necessitating effective management strategies to achieve higher yields. Indiscriminate use of chemical insecticides leads to resistance and environmental harm. This study was conducted at the Central Research Farm, BCKV, West Bengal, evaluating eight treatments including indigenous biopesticides, azadirachtin formulations, and synthetic insecticides. Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% EC @1 ml/L (T6) recorded the lowest infestations of whiteflies (2.18/3 leaves), jassids (2.89/3 leaves), and aphids (2.64/3 leaves), followed by Chlorfluazuron @2 ml/L (T7) (4.11 aphids/3 leaves), Indigenous biopesticides + Azadirachtin @50+2 ml/L (T5) (4.64 aphids/3 leaves), and Indigenous biopesticides + Azadirachtin @30+2 ml/L (T4) (4.99 aphids/3 leaves). Percent reduction of jassids over untreated control was highest in T6 (71.16%), followed by T7 (54.63%), T5 (50.75%), T4 (48.27%), and Azadirachtin 10000 ppm @50 ml/L (T3) (39.82%). These results demonstrate the efficacy of integrating chemical and eco-friendly approaches for sustainable okra production.

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## **Pioneering Biointensive IPM: Sustainable Yield Amplification for Vegetable and Flower Crops**

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The escalating global demand for food necessitates sustainable pest control strategies, moving beyond the ecological harm of indiscriminate chemical pesticides, which cause biodiversity loss and residue accumulation. Bio-intensive Pest Management offers an ecologically sound paradigm, integrating biopesticides, microbial agents, and cultural practices within comprehensive IPM systems. This approach aims to reduce reliance on synthetic inputs, promoting enhanced economic returns and minimizing environmental impact, driven by consumer demand for residue-free produce. While BIPM improves crop yields and ecological integrity in vegetable crops, challenges remain in ensuring the consistent efficacy and commercial viability of biological alternatives under diverse field conditions. Vegetable and flower crops are highly susceptible to insect pests and diseases, and the indiscriminate use of chemical pesticides has caused serious ecological problems, including the destruction of natural enemy populations, harm to non-target organisms, residues in food and water, and the development of pesticide resistance. Bio-intensive pest management (BIPM) has emerged as a modern approach in Indian agriculture, attracting farmers due to its potential to increase income while reducing ecological harm.