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Climate Change and Emerging Insect Pests: Unraveling the Silent Crisis in Indian Agriculture

*Amruth S
Department of Agricultural Entomology, University of Agricultural Sciences, GKVK, Bengaluru 560065, Karnataka, India
*Corresponding Author's email: amruthagriculture@gmail.com

Indian agriculture stands at an intricate crossroad. While the national discourse on climate change frequently revolves around water scarcity, heatwaves, and declining crop yields, an equally devastating but stealthier adversary is operating within farm canopies: the dramatic restructuring of insect pest dynamics. Being poikilothermic (cold-blooded) organisms, insects are exquisitely sensitive to minute fluctuations in ambient temperature, atmospheric moisture, and carbon dioxide levels. As India experiences warmer winters, compressed spring seasons, extended dry spells, and untimely monsoon downpours, the ecological balances refined over centuries are unraveling. Historically minor or localized insect species are transforming into devastating primary pests, while alien invasive species find newly hospitable thermal niches across India's 15 agro-climatic zones. From the sudden surge of the invasive South American pinworm (*Tuta absoluta*) in tomato belts to the relentless assault of the invasive alien black thrips (*Thrips parvispinus*) across southern chilli tracts, climate perturbations are rewriting the textbooks of economic entomology. Understanding these shifts is no longer merely an academic exercise; it is an urgent imperative for India's food security, rural livelihoods, and agricultural sustainability.

Mechanisms of Climate-Driven Pest Virulence in Tropical Agriculture

- **Thermal Acceleration & Increased Voltinism:** Higher baseline temperatures shorten egg incubation and nymphal instars, enabling insects like aphids, planthoppers, and whiteflies to complete additional generations per cropping season (multivoltinism).
- **Expanded Overwintering Survival:** Milder winter temperatures in the Indo-Gangetic Plains (IGP) eliminate natural mortality checkpoints, allowing robust spring pest populations to establish weeks earlier than historic averages.
- **Host-Plant Compensatory Feeding under Elevated CO_2:** Enriched CO_2 dilutes leaf nitrogen and increases carbon-to-nitrogen (C:N) ratios, compelling chewing caterpillars to consume 20–40% more leaf biomass to meet basic metabolic nitrogen needs.
- **Asynchronous Tritrophic Mismatch:** Rising temperatures accelerate pest development faster than that of their specialized parasitoids and predators, creating temporal 'enemy-free windows' of unchecked proliferation.

System-Wise Vulnerabilities Across Indian Cropping Landscapes

A. Cereal Ecosystems: Rice, Wheat and Coarse Grains

In the rice-wheat cropping system of the Indo-Gangetic Plains, microclimatic shifts coupled with altered agronomic practices have triggered unprecedented pest dynamics. In paddy, the Brown Planthopper (*Nilaparvata lugens*) and Whitebacked Planthopper (*Sogatella furcifera*) have experienced explosive resurgence. Prolonged warm, humid canopy conditions favor rapid hopper development, while late-season unseasonal rainfalls prevent effective biological suppression, causing devastating 'hopper burns'.

In wheat, the Pink Stem Borer (*Sesamia inferens*), historically a pest confined to rice and maize, has aggressively expanded into the wheat crop across Punjab, Haryana, and Western Uttar Pradesh. The widespread adoption of zero-tillage and Happy Seeder technologies, combined with warmer November temperatures, facilitates the survival of larvae in retained rice stubbles, which then migrate directly into newly germinating wheat seedlings.

In maize and millets, the Fall Armyworm (*Spodoptera frugiperda*), since its initial invasion in 2018, has become entrenched across peninsular and central India. Because FAW exhibits extreme thermal plasticity and high reproductive capacity, warmer winter cycles allow continuous, non-diapausing breeding on off-season fodder crops and sweet corn.

B. Commercial and Horticultural Tracts: The Sucking Pest Complex

Nowhere is the fingerprint of climate change more glaring than in the rapid escalation of the sucking pest complex in commercial and horticultural belts:

• The Polyphagous Thrips Invasion (*Thrips parvispinus*): First detected in Andhra Pradesh and Telangana, this invasive pest devastated extensive chilli tracts in Southern India. Unlike native thrips (*Scirtothrips dorsalis*) that colonize foliage and tender shoots, *T. parvispinus* colonizes flowers, severing floral organs and inducing complete fruit abortion. Elevated temperatures during dry spells trigger hyper-exponential population buildups that conventional synthetic chemical rotations fail to curtail.

• Whitefly Species Complex (*Bemisia tabaci*) and Viral Epiphytotics: Extended hot and dry spells in north-western cotton belts (Punjab, Rajasthan and Haryana) induce explosive whitefly flare-ups. Beyond direct phloem-sap drainage, *B. tabaci* serves as the potent vector for Cotton Leaf Curl Virus (CLCuV). Elevated temperatures enhance viral transmission efficiency, leading to widespread economic crop failures.

• Invasive Spiralling Whiteflies in Plantation Belts: Rugose Spiralling Whitefly (*Aleurodicus rugioperculatus*) has expanded across coastal Karnataka, Kerala and Tamil Nadu, infesting coconut and oil palm plantations. Sooty mold encrustation on fronds severely disrupts photosynthesis, exacerbated by prolonged post-monsoon dry conditions.

Comprehensive Matrix: Emerging Insect Pests Under Climate Drivers

Crop Ecosystem	Emerging / Resurgent Pest	Key Climatic & Environmental Triggers	Primary Damage / Agricultural Threat
Rice	Brown Planthopper (*Nilaparvata lugens*)	High humidity, extended thermal windows, non-judicious N-fertilization	Widespread hopper burn, transmission of ragged & grassy stunt viruses
Wheat	Pink Stem Borer (*Sesamia inferens*)	Milder Novembers, larval carryover in zero-till rice stubbles	Dead-hearts in young tillers, reduced effective ear-head count
Maize & Millets	Fall Armyworm (*Spodoptera frugiperda*)	Absence of freezing winters, polyphagous bridge hosts, erratic rain	Foliar skeletonization, whorl destruction, ear rot susceptibility
Chilli & Vegetables	Black Thrips (*Thrips parvispinus*)	Prolonged dry spells, elevated baseline summer temperatures	Severe floral shedding, blossom laceration, up to 80% yield loss
Cotton	Whitefly complex (*Bemisia tabaci*)	Hot & dry pre-monsoon spells, delayed monsoon arrival	Severe phloem sap depletion, widespread Cotton Leaf Curl Virus (CLCuV)
Pigeonpea / Pulses	Gram Pod Borer (*Helicoverpa armigera*)	Elevated CO_2 induced foliage feeding, winter temperature spikes	Extensive pod boring, resistance escalation against synthetic sprays
Mustard	Mustard Aphid (*Lipaphis erysimi*)	Overcast skies, sudden winter warming during siliqua formation	Colony engulfment of inflorescence, stunted pods, oil yield crash

The Broken Natural Shield: Tritrophic Mismatch & Biocontrol Failure

A critically overlooked fallout of climatic destabilization is the uncoupling of natural biological control systems. In temperate and tropical agro-ecosystems, biological suppressors such as parasitic micro-hymenopteran wasps (e.g., *Trichogramma spp.*, *Cotesia spp.*, *Encarsia formosa*) and predatory coccinellid beetles maintain equilibrium. However, research demonstrates that natural enemies frequently possess lower thermal upper thresholds than their phytophagous hosts. When daytime temperatures cross 38°C–40°C during peak agricultural months, egg parasitoids suffer dramatic drops in fecundity, adult longevity, and searching efficiency, while pests like aphids and lepidopteran borers continue metabolizing and reproducing. Furthermore, volatile organic compound (VOC) signaling from pest-infested host plants—the biochemical distress flares that attract beneficial parasitoids—undergoes chemical degradation or altered emission rates under elevated ozone and heat stress, effectively blinding nature's bio-defenses.

Climate-Smart Integrated Pest Management (CS-IPM): The Strategic Roadmap

Tackling this complex entomological crisis demands transitioning from calendar-based chemical applications toward forward-looking, climate-smart agro-ecological interventions. Indian agriculture requires a five-pillar action strategy:

- **AI-Powered Agro-Meteorological Early Warning Systems:** Integrating automated pheromone sensor traps with regional weather forecasting portals (e.g., IMD Meghdoot, CROPSAP) allows hyper-local degree-day modeling. Forecasting pest emergence windows 7–10 days in advance empowers farmers to initiate targeted bio-rational interventions before threshold breaches.
- **Multi-Stress Tolerant Crop Varieties:** Breeding programs must focus on stacking insect-pest resistance traits (QTLs) with climate-resilience traits (drought and thermal tolerance). For instance, wild introgressed rice genotypes exhibiting robust silicon deposition strengthen mechanical leaf toughness against stem borers and hoppers.
- **Thermal-Stable Microbial Bio-Pesticides:** Standard entomopathogenic fungi (*Beauveria bassiana*, *Metarhizium anisopliae*) degrade rapidly under intense UV radiation and ambient heat above 35°C. Developing oil-based formulations and nano-encapsulated biopesticides enhances environmental field persistence during extreme weather episodes.
- **Ecological Engineering & Habitat Diversification:** Transforming monocultures through border crops (e.g., maize and sorghum around cotton; marigold and cowpea intercropping in pulses) conserves natural predatory fauna, acts as physical barrier traps, and creates microclimatic refugia for beneficial insect communities.
- **Strengthened Phytosanitary Quarantine & Biosecurity:** Climate change broadens the ecological gateway for exotic invasives. Upgrading molecular diagnostic tools at international ports and establishing rapid-response sentinel plots along vulnerable agro-ecological borders are paramount.

The Way Forward: Cultivating Climate-Resilient Entomo-Security

The emerging pest scenarios in Indian agriculture are not isolated seasonal anomalies; they represent a fundamental structural shift in tropical agro-ecology. Relying purely on higher chemical pesticide dosages is an ecological dead-end that exacerbates resistance, induces secondary pest flare-ups, elevates residues, and destroys non-target pollinators. By embracing Climate-Smart Integrated Pest Management (CS-IPM), fusing cutting-edge bio-surveillance with ecological engineering, and equipping smallholder farmers with actionable forecasts, Indian agriculture can safeguard its yields and secure farm incomes amidst a warming world.

Key Policy & Extension Actionables

✔ Re-calibrate Economic Threshold Levels (ETLs) to account for accelerated pest voltinism under higher temperature regimes.

✔ Establish regional Bio-Control Mass Production Centers to supply heat-tolerant strains of beneficial parasitoids and entomopathogens.

✔ Mandate digital pest reporting across Krishi Vigyan Kendras (KVKs) for real-time national pest mapping and proactive quarantine action.

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