Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 06, Issue: 01 (JAN-FEB, 2026)
Available online at http://www.agriarticles.com

Smart Pest Control: Using Insect Behaviour Instead of Chemicals

*Rahul Nodal[1], Abhay Tak[2], Pavitra Choudhary[3] and Hemanth B A[4]
[1]Dept. of Entomology, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan
[2]Department of Entomology, SHUATS, Prayagraj, UP
[3] Entomology Dept., College of Agriculture, Agriculture University, Jodhpur, Rajasthan
[4]Department of Entomology, College of Agriculture, UAS, Bangalore
*Corresponding Author's email: amarchahar15@gmail.com

Smart pest control is an emerging approach that uses insect behaviour instead of relying primarily on chemical pesticides. This strategy focuses on understanding how insects communicate, move, feed, reproduce and then manipulating these behaviours to reduce crop damage in an environmentally friendly way. Key techniques include pheromone traps that disrupt mating, light and colour traps that attract specific pests and push-pull systems that repel insects from crops while attracting them to trap plants. By targeting behaviour, these methods can reduce pest populations without leaving harmful residues on food, soil or water. Behaviour-based control also helps slow the development of pesticide resistance, a major problem in conventional chemical control. In addition, it supports natural enemies such as predators and parasitoids, which are often harmed by broad-spectrum insecticides. Smart pest control can be integrated with modern tools like remote sensing, field sensors and decision-support systems to monitor pest activity and apply interventions only when needed. This makes pest management more precise, cost-effective and sustainable. Overall, using insect behaviour for pest control offers a promising pathway towards safer food production, protection of biodiversity and long-term agricultural resilience.

Keywords: Insect behaviour; semiochemicals; pheromones; push–pull; attract-and-kill; mating disruption; sustainable agriculture

Introduction

Insect pests destroy an estimated 20% of global crops annually, a burden expected to rise as climate change expands pest ranges and disrupts ecological balances (Belagalla *et al.*, 2024). Chemical pesticides once looked like a miracle fix for crop losses and household pests. Today, they are linked to pollution, declining biodiversity and growing waves of insecticide resistance, where pests simply evolve to survive higher and higher doses (Siddiqui *et al.*, 2023). This is pushing farmers and scientists toward a different question: instead of poisoning insects, what if we outsmart them?

In parallel, many insects that damage crops are guided to their hosts and mates through highly refined sensory and behavioural mechanisms. They use long range plant volatiles, short range contact chemicals and species-specific pheromones, processed by sophisticated olfactory and gustatory systems, to make decisions about feeding and oviposition. These same pathways can be exploited by the use of semiochemicals; such chemicals are usually informative in nature such as pheromones, kairomones, and herbivore-induced volatiles, and now semiophysical cues such as light and substrate-borne vibrations. (Anton and Cortesero, 2022).

How Insects "See" the World

Insects navigate mainly with smell, taste, sound, vibration, light and touch. They follow scent plumes to find crops, mates and egg-laying sites, guided by pheromones and plant odours known as semiochemicals. Many pests also rely on subtle cues like humidity changes, colors and even substrate vibrations for feeding and mating.

Because behaviour is so tightly linked to these signals, changing the signals can change what insects do. This is the foundation of behaviour-based, low-chemical pest control.

Turning Insects' Own Signals Against Them

- In fact, whole toolkits have been developed that manipulate behaviour instead of kill on contact:
- **Pheromone traps and mating disruption:** Synthetic sex pheromones lure males into traps or flood the air so they can't find females, sharply reducing mating success. This tactic already is widely used in crops, especially against moth pests and is being expanded for stored-product insects. (Morrison *et al*., 2021).
- **Attract and kill and mass trapping:** Food attractive odours, plant volatiles, or kairomones (attractive scents of plants/microorganisms) entice insects towards bait traps or small areas where the confined insecticide is applied, reducing the usage of chemicals. For example, fermenting microbes added to lures make fruit-fly traps dramatically more attractive (Mazzoni and Anfora, 2021).
- **Push–pull systems:** Farmers can "push" insects away from the main crop with repellent plants or odours, while "pulling" them into border traps or sacrificial plants using attractive cues (Masiulionis and Samuels, 2025). This spatial choreography reduces damage without blanket spraying.
- **Repellents, masking and confusion:** Certain plant compounds or essential oils repel insects or mask the smells they use to recognize host plants, making crops effectively invisible or unattractive (Kansman *et al*., 2023). Disrupting these recognition cues can prevent pests from ever settling to feed.

Beyond Smell: Light, Sound and Vibration

Insects do not communicate with chemicals alone. Some pests are drawn to specific wavelengths of light, others use vibrational "songs" for mating. Modern "smart" traps now combine visual cues, chemical lures and cameras to automatically count even tiny insects like thrips, sending real-time data to farmers' phones. Entomologists call non-chemical sensory cues like light and vibration "semiophysicals" and combining them with semiochemicals can powerfully steer pest behaviour (Nieri *et al*., 2021).

Smarter Monitoring Means Less Spraying

Behaviour-based tools are also transforming monitoring. Instead of spraying "just in case," farmers can:

- Use pheromone or kairomone traps to detect when a pest first appears;
- Spray only when trap counts exceed an economic threshold;
- Or, in some systems, replace spraying altogether with annihilation trapping or mating disruption (Belagalla *et al*., 2024).

This fits perfectly within Integrated Pest Management (IPM), which aims to combine biological control, host-plant resistance, physical barriers and highly targeted interventions to keep pests below damaging levels while protecting the environment (Belagalla *et al*., 2024).

Why Behavioural Control Is Gaining Momentum

Several pressures are accelerating this shift:

- **Resistance**: heavy pesticide use has led many insect species to evolve robust resistance, making chemicals less reliable (Civolani *et al*., 2025).
- **Regulation and public concern**: many toxic insecticides are being progressively banned, especially in Europe, which is pushing alternatives into the limelight (Siddiqui *et al*., 2023).

- **Environmental and health impacts**: soil, water, non-target insects (such as pollinators) and human exposure to these drive the need for more environmentally friendly tools (Siddiqui *et al*., 2023).

Behaviour-based methods directly address these issues by being species-specific, low-residue and compatible with natural enemies (Nieri *et al*., 2021).

What's Holding Behavioural Control Back?

Despite its promise, scientists note that behaviour-based methods are still underused:

- Pest insects are often attracted by strong food scents, which may be more dominant than artificial lures, particularly in food facilities (Morrison *et al*., 2021).
- There are often multiple pest species on a given farm, each with its own chemical language, which makes "one-scent-fits-all" solutions challenging (Morrison *et al*., 2021
- Adoption may be delayed due to cost, a lack of awareness, and the belief that "real" control is demonstrated by visible pesticide use (Siddiqui *et al*., 2023).

The Future: Precision, AI and Multi-Modal "Smart" Systems

Emerging research points toward multi-modal, data-driven pest control:

- Integrated systems that combine semiochemicals + light/vibration + physical barriers, tailored to each crop and pest community (Nieri *et al*., 2021).
- "Smart traps" linked to AI image recognition, producing precise pest population maps that guide local interventions instead of field-wide sprays (Belagalla *et al*., 2024).
- Crops bred or engineered to emit different volatile blendsless attractive to pests, more attractive to their natural enemies—effectively re-wiring the communication network in a field (Kansman *et al*., 2023).

A New Narrative for Pest Control

Behaviour-based pest management does not promise a world with zero chemicals. Instead, it reframes chemicals as surgical tools of last resort in a broader strategy built on ecology, behaviour and precision (Belagalla *et al*., 2024). Through the observation of the communication of insects via olfactory, visual and vibrational signals and the subsequent adjustment of these signals, agricultural practitioners can protect their crops, reduce environmental pollution and maintain biodiversity, which is crucial in agricultural systems.

References

1. Anton, S., and Cortesero, A. (2022). Plasticity in Chemical Host Plant Recognition in Herbivorous Insects and Its Implication for Pest Control. *Biology*, 11. https://doi.org/10.3390/biology11121842
2. Belagalla, N., Kaur, R., and Abhishek, G. (2024). Eco-friendly and Targeted through Next-generation Approaches to Insect Pest Management. *UTTAR PRADESH JOURNAL OF ZOOLOGY*. https://doi.org/10.56557/upjoz/2024/v45i134137
3. Civolani, S., Bariselli, M., Osti, R., and Bernacchia, G. (2025). Insect Pest Control from Chemical to Biotechnological Approach: Constrains and Challenges. *Insects*, 16. https://doi.org/10.3390/insects16050528
4. Kansman, J., Jaramillo, J., Ali, J., and Hermann, S. (2023). Chemical ecology in conservation biocontrol: new perspectives for plant protection.. *Trends in plant science*. https://doi.org/10.1016/j.tplants.2023.05.001
5. Masiulionis, V., and Samuels, R. (2025). Investigating the Biology of Leaf-Cutting Ants to Support the Development of Alternative Methods for the Control and Management of These Agricultural Pests. *Agriculture*. https://doi.org/10.3390/agriculture15060642
6. Mazzoni, V., and Anfora, G. (2021). Behavioral Manipulation for Pest Control. *Insects*, 12. https://doi.org/10.3390/insects12040287
7. Morrison, W., Scully, E., and Campbell, J. (2021). Towards developing areawide semiochemical-mediated, behaviorally-based integrated pest management programs for stored product insects.. *Pest management science*. https://doi.org/10.1002/ps.6289

8. Nieri, R., Anfora, G., Mazzoni, V., and Stacconi, M. (2021). Semiochemicals, semiophysicals and their integration for the development of innovative multi-modal systems for agricultural pests' monitoring and control. *Entomologia Generalis*. https://doi.org/10.1127/entomologia/2021/1236
9. Siddiqui, J., Fan, R., Naz, H., Bamisile, B., Hafeez, M., Ghani, M., Wei, Y., Xu, Y., and Chen, X. (2023). Insights into insecticide-resistance mechanisms in invasive species: Challenges and control strategies. *Frontiers in Physiology*, 13. https://doi.org/10.3389/fphys.2022.1112278