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Biorational Approaches: An Eco-Friendly Pest Management

*Priyanka S M

PhD Scholar, Department of Entomology, Indira Gandhi Krishi Vishwavidyalaya,
Raipur, Chhattisgarh, India

*Corresponding Author's email: priyankapky2002@gmail.com

Biorational approaches represent environmentally safe and selective strategies for pest management within the framework of Integrated Pest Management. These methods regulate insect populations by affecting their growth, development, behaviour and reproduction rather than causing immediate toxicity. Biorational control includes techniques such as insect growth regulators (IGRs), antifeedants, attractants, repellents, chemosterilants and microbial control agents like bacteria, viruses and fungi. These approaches minimize ecological disruption, reduce harmful pesticide residues and protect beneficial organisms. Compounds such as juvenile hormone analogues, chitin synthesis inhibitors, neem-based products, and pheromone traps are widely used for sustainable pest suppression. Although their action may be slower compared to conventional pesticides, biorational methods provide long-term ecological stability and support sustainable agricultural production while reducing risks to human health and the environment.

Keywords: Biorational pesticide; Integrated Pest Management; Insect Growth Regulators; Microbial control.

Introduction

The idea of Integrated Control was initially proposed by Stern and co-workers in 1959 during a period dominated by intensive application of broad-spectrum chemical insecticides such as organochlorines, organophosphates, carbamates and synthetic pyrethroids. Although these insecticides effectively suppressed pest populations, their indiscriminate and prolonged usage resulted in environmental contamination, pest resurgence, ecological disruption and risks to human health. Growing environmental awareness and societal concern necessitated the development of safer and ecologically compatible pest management strategies. Consequently, the concept of Integrated Pest Management (IPM) emerged as a holistic approach combining different control tactics. Modern IPM philosophies emphasize risk minimization by reducing adverse impacts of pest management practices on ecosystems, biodiversity and human welfare. Adoption of reduced-risk technologies, particularly biorational approaches, has therefore become essential for sustainable agricultural production systems.

Biorational Control

Biorational control involves the regulation of insect populations through substances or techniques that specifically influence insect physiology, behaviour, development or reproductive processes rather than causing immediate toxicity. These approaches aim to achieve effective pest suppression with minimal ecological disturbance.

Biorational pesticides:

Conventional synthetic pesticides often harm non-target organisms and degrade environmental quality. Therefore, considerable efforts have been made over recent decades to develop safer and selective pest control agents known as biorational pesticides, which present lower ecological risk.

Methods included under biorational control are: Insect Growth Regulators (IGRs), Chitin synthesis inhibitors, Juvenile hormone analogues and anti-juvenile hormones, Moulting hormones, Pheromones and allelochemicals, Attractants, repellents and antifeedants, Chemosterilants and Sterile male release techniques

1. INSECT GROWTH REGULATORS

Insect Growth Regulators are specialized compounds that interrupt normal insect growth, differentiation, and metamorphosis. These substances may function either by mimicking natural insect hormones or by inhibiting essential physiological pathways required for development.

Natural hormones of insects which play a role in growth and development are

1. **Brain Hormone (Activation Hormone):** Secreted by neurosecretory cells of the central nervous system, this hormone stimulates endocrine glands responsible for juvenile hormone production.
2. **Juvenile Hormone (JH):** Produced by corpora allata glands, juvenile hormone maintains larval characteristics and prevents premature metamorphosis. Reduction in JH concentration triggers progression toward pupal and adult stages, while specific forms contribute to reproductive maturation in adult insects.
3. **Ecdysone (Moulting Hormone):** Synthesized by prothoracic glands, ecdysone regulates moulting processes essential for insect growth. Absence or imbalance of this hormone disrupts normal development.

IGRs used in Pest management

- a) **Ecdysoids:** Synthetic compounds resembling natural moulting hormones that induce abnormal cuticle formation and developmental failure.
- b) **Juvenoids (JH mimics):** They are synthetic analogues of Juvenile Hormone (JH). They are most promising as hormonal insecticides. JH mimics were first identified by Williams and Slama in the year 1966. They found that the paper towel kept in a glass jar used for rearing a *Pyrrhocoris* bug caused the bug to die before reaching adult stage. They named the factor from the paper as 'paper factor' or 'juvabione'. Juvenoids are larvicidal and ovicidal in action and they disrupt diapause and inhibit embryogenesis in insects. Methoprene is widely used against several agricultural pests.
- c) **Anti JH or Precocenes:** Precocenes inhibit juvenile hormone synthesis by damaging corpora allata, leading to premature development of sterile adults incapable of reproduction. Eg. EMD, FMeV, and PB (Piperonyl Butoxide)
- d) **Chitin Synthesis inhibitors:** Compounds such as benzoyl phenyl ureas interfere with chitin formation, preventing proper exoskeleton development and successful moulting. Two important compounds in this category are Diflubenzuron (Dimilin) and Penfluron.
- e) **IGRS from Neem:** Azadirachtin present in neem extracts disrupts insect growth, reduces fecundity, and induces developmental deformities.

2) ANTIFEEDANTS

Antifeedants are compounds that deter insects from consuming treated plant surfaces without repelling them physically. Feeding inhibition ultimately leads to starvation and population decline. They are also called gustatory repellents, feeding deterrents and rejectants. Since they do not feed on treated surfaces they die due to starvation.

Groups of antifeedants

- A. **Triazenes:** AC 24055 is a colourless, odourless, and non-toxic compound that suppresses feeding behaviour in chewing insects such as caterpillars, cockroaches, and beetles.
- B. **Organotin Compounds:** Organotin compounds contain tin as a major component. Among them, triphenyl tin acetate functions as an effective antifeedant against pests like cotton leaf worm, Colorado potato beetle, caterpillars, and grasshoppers.
- C. **Carbamates:** At sublethal concentrations, thiocarbamates and phenyl carbamates act as feeding deterrents to foliage-feeding insects including caterpillars and the Colorado potato beetle. Baygon serves as a systemic antifeedant particularly effective against cotton boll weevil.

- D. **Botanical Antifeedants:** Plant-derived compounds obtained from non-host plants of insect pests can be utilized as natural feeding deterrents. Several important antifeedants originate from botanical sources.
- E. **Pyrethrum:** Pyrethrum, obtained from the flowers of *Chrysanthemum cinerarifolium*, exhibits antifeedant activity at low concentrations against biting flies such as *Glossina* species.
- F. **Neem:** Extracts prepared from leaves and fruits of neem (*Azadirachta indica*) possess strong antifeedant properties and are especially effective against a wide range of chewing insects, including desert locusts.
- G. **Apple Factor:** Phlorizin, a compound derived from apple tissues, acts as an antifeedant against aphid species that do not normally infest apple plants.
- H. **Solanum Alkaloids:** Alkaloids such as leptine, tomatine, and solanine extracted from *Solanum* species function as feeding deterrents against pests like leafhoppers.

3) INSECT ATTRACTANTS

Insect attractants are chemical stimuli that guide insects toward a particular source by activating olfactory or gustatory receptors. They influence both gustatory (taste) and olfactory (smell) receptors.

Types of Attractants:

- a) **Pheromones:** Pheromones are chemical substances released by an insect into the surrounding environment that trigger a specific behavioural or physiological response in another individual of the same species. These chemicals play an important role in communication, particularly in mating behaviour. Example: Sex pheromone traps containing (*Z*)-11-hexadecenal are widely used to attract male pink bollworm (*Pectinophora gossypiella*) in cotton fields for monitoring and population control.
- b) **Food Attractants (Food Lures):** Food attractants are naturally occurring chemical compounds present in host plants or food materials that draw insects toward them for feeding. These substances mainly stimulate the insect's olfactory (smell) receptors. Example: Protein hydrolysate bait is commonly used to attract fruit flies (*Bactrocera dorsalis*) towards traps in fruit orchards.
- c) **Oviposition Attractants (Egg-laying Lures):** Oviposition attractants are chemicals that influence female insects in selecting suitable locations for egg deposition. These compounds mimic host plant cues that indicate favourable conditions for offspring development. Example: Corn extract or plant volatiles attract female *Helicoverpa armigera*, encouraging egg laying on treated surfaces used in monitoring or pest management programmes.

4) INSECT REPELLENTS

Insect repellents are substances that cause insects to move away from their source by inducing avoidance behaviour. These compounds protect plants, animals, and humans from insect attack by making the treated surface unattractive, unpleasant, or unsuitable for feeding or settlement.

Types of repellents

1. Physical Repellents

Physical repellents discourage insects through mechanical or sensory effects rather than chemical toxicity.

- a) **Contact Stimulus Repellents:** These substances alter the surface characteristics of plant parts, making them unsuitable or uncomfortable for insect contact or feeding. Example: Application of mineral oils or wax coatings on citrus leaves discourages infestation by aphids and whiteflies.
- b) **Auditory Repellents:** High-frequency sound waves interfere with insect orientation and help drive them away. Example: Ultrasonic sound devices are used to repel mosquitoes in residential areas.

- c) **Barrier Repellents:** Physical obstacles prevent insect movement or access to host plants or animals. Example: Tar bands placed around tree trunks prevent climbing insects such as mango mealybugs; mosquito nets act as barriers against mosquito entry.
- d) **Visual Repellents:** Certain light wavelengths or visual signals deter insects from approaching treated areas. Example: Yellow or reflective light sources repel some nocturnal insects in storage and residential environments.
- e) **Feeding Repellents:** These substances inhibit feeding activity without necessarily driving insects away immediately. Antifeedants fall under this category. Example: Neem-based formulations prevent feeding by caterpillars on vegetable crops.

2. Chemical repellents:

- a) **Plant-Derived Repellents:** Natural compounds extracted from plants that emit odours or chemicals disliked by insects. Examples: Citronella oil obtained from lemongrass (*Cymbopogon* spp.) repels mosquitoes and camphor and cedarwood oils act as repellents against stored-product pests.
- b) **Synthetic Repellents:** These are artificially manufactured chemicals designed to repel insects effectively for longer durations. Examples: DEET (N,N-diethyl-meta-toluamide) widely used in mosquito repellent lotions and sprays.

5. CHEMOSTERILANTS:

Chemosterilants are chemical agents that impair insect reproductive capability, thereby suppressing population growth.

- **Alkylating agents** disrupt nucleic acid synthesis and reproductive organ development.
- **Antimetabolites** interfere with metabolic pathways essential for reproduction.

6. MICROBIAL CONTROL

Microbial control refers to the management of insect pests through the application of pathogenic microorganisms such as viruses, bacteria, protozoa, fungi, rickettsia, and nematodes that infect and suppress pest populations.

1. Viral Control: Certain insect-pathogenic viruses belonging to the family Baculoviridae are widely used for controlling larval stages of lepidopteran insects. These viruses infect and multiply within the host, ultimately causing disease and death. Commonly used viral groups include:

- Nucleopolyhedrovirus (NPV) – examples include *Helicoverpa armigera* NPV (HaNPV) and *Spodoptera litura* NPV (SINPV).
- Granulovirus (GV) – for example, *Cydia pomonella* granulovirus (CiGV).

2. Bacterial Control: Bacteria that infect and kill insect pests are known as entomopathogenic bacteria. These microorganisms produce toxins that disrupt the digestive system of insects after ingestion. Example: *Bacillus thuringiensis* (*Bt*) is extensively used for the control of lepidopteran caterpillars in agricultural crops.

3. Fungal Control: Fungi capable of infecting and killing insects are termed entomopathogenic fungi. These fungi penetrate the insect body through the cuticle and proliferate internally, leading to mortality. Important examples include:

- Green muscardine fungus – *Metarhizium anisopliae*, effective against coconut rhinoceros beetles.
- White muscardine fungus – *Beauveria bassiana*, used against lepidopteran larvae.
- White halo fungus – *Verticillium lecanii*, effective in controlling coffee green scale insects.

Advantages of Biorational Approaches

- Eco-friendly and safer to beneficial organisms.
- Supports long-term ecological stability.
- High specificity toward target pests.
- Compatible with integrated pest management systems.
- Produces minimal chemical residues.

Disadvantages of Biorational Approaches

- Performance may vary under field conditions.
- Slower pest suppression compared to conventional pesticides.
- Limited commercial accessibility in certain regions.
- Requires continuous monitoring and management.
- Possible ecological risks if improperly introduced.

Conclusion

Integrated Pest Management represents a sustainable and adaptive framework that integrates surveillance, ecological understanding, and compatible control measures for effective pest suppression. Future IPM strategies should prioritize ecological restructuring and system-based approaches rather than relying solely on chemical substitution. Strengthening ecological interactions within agro-ecosystems remains essential for achieving durable and environmentally sound pest management solutions.

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