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Biorational Insecticides: Reduced-Risk Pesticides, Their Potential Ecological Impact and Reliablity in IPM

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Introduction

Due to changing patterns in insect infestations and climatic conditions, global agriculture is currently challenged to supply increasing quantities of food for a rising population. There is overwhelming evidence that the use of chemical pesticides has resulted in a slew of other serious issues, including ecological backlash in pest species, environmental pollution and degradation, threats to biodiversity conservation, insecticide resistancecausing crisis proportions, loss of beneficial fauna (predators, parasites, pollinators, etc.),toxicity to non-target organisms, and, in particular, human beings, have driven demand for alternative pest control tactics. “Biorational pesticides” has only recently been proposed term derived from two words, “biological” and “rational” referring to pesticides that are synthetic or natural compounds effective against the target pest but are less detrimental to natural enemies. Taking into account that the new generation of pesticides has gained attention in pest management in recent years, biorational pesticides, also known as "third-generation pesticides," are derived from some natural source and pose minimal or no adversarial threats to the environment and beneficial organisms. Biorational pesticides include the microbiological pesticide *Bacillus thuringiensis* (Kurstaki), neonicotinoids, avermectins, phenlpyrazoles, spinosyns, pyrroles, oxadiazines, and numerous insect growth regulators (IGR).

These have notable advantages in terms of efficacy, specificity in terms of modes of action, and safety to non-target species, *i.e.* having a very narrow pest target range. Insecticide resistance is mostly caused by the injudicious, indiscriminate, and frequent use of conventional insecticides, and it may be countered with the use of biorationals. This new class of pesticides is mainly designed to restrict a pest population to a manageable level rather than totally eradicate a specific pest, and should be regarded as 'selective insecticides,' which are approximately fully compatible with biologicals. These chemicals offer a high potential for replacing persistent conventional pesticides, demonstrating an effective cost-benefit ratio, addressing ecological backlash, and providing food security in a safe environment. The area of biorational pesticides is vast, and is a source of both excitement and anxiety. However, these bio-products are not only gaining market reliability and end-user trust, but also demonstrating their worth and potential in long-term IPM programmes that will reduce the use of chemical pesticides.

Classification of Biorational Pesticides:

The following are the key categories of biorational pesticides:

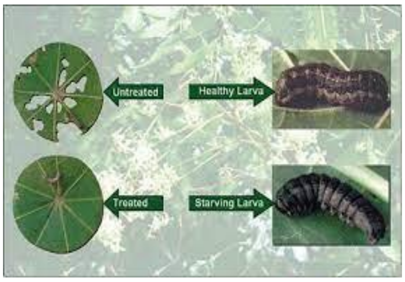
1. Microbials (viruses, bacteria,fungi and protozoa),
2. Phytochemicals,and
3. Biochemicals (botanicals, IGRs and pheromones).

1. Microbial Pesticides:

Microbial insecticides are chemicals that include microbes or by-products of microorganisms that cause insect illnesses. Bacteria, fungi, viruses, and protozoans are among the biorational pesticides. These insecticides can control a wide range of pests, while each active ingredient is generally specific to its target pest.

Viruses: Many distinct forms of entomopathogenic viruses attack insects. These viruses are obligatory disease-causing organisms that can only replicate within a host insect. Only Baculoviruses (BVs), which are categorized into two genera: Nuclear Polyhedro Virus (NPV) and Granulovirus (GV), have been employed as insecticides. BVs are responsible for the virus's systemic or cell-to-cell transmission within an infected insect. Baculovirus control of pest insect populations was proven in the 1940s, but *Helicoverpa* (*Heliothis*) *zea* was the first viral pesticide to be licenced in 1971 under the trade name Elcar. A number of baculovirus pesticides have been approved for commercial use, mainly for caterpillars on cotton, row crops, fruits and vegetables.

Bacteria: *Bacillus thuringiensis* (*Bt*) is the most frequently utilized insecticidal bacterium. It is a gram-positive, spore-forming soil bacteria that is pathogenic to the larvae of some insects, notably lepidopterous insects, inducing death by infection. The bacterium's endospore



includes endotoxins capable of paralysing and lysing the insect stomach, resulting in death by starvation. These are highly efficient, easily be mass-produced,easy to handle, stable when stored, cost-effective, pest specific, and safe topeople and the environment and must be incorporated in IPM programs.There are severalinsecticides based on various sub-species of *Bacillus thuringiensis* Berliner(*Bt*), such as *B. thuringiensis israelensis*(*Bti*) againstmosquito larvae;*B. thuringiensis tenebrionis*(*Btt*) against coleopteran adults and larvae; *B. thuringiensis kurstaki*(*Btk*) and *B. thuringiensis aizawai*(*Bta*)against lepidopteran larval species; and*B. thuringiensis japonensis*(*Btj*) strain *buibui*against soilinhabitingbeetles. Abamectin, Ivermectin and Emamectin benzoateproduced from*Streptomycesavermitilis* and spinosad produced from bacteria, *Saccharopolyspora spinosa.*

Fungi: Many fungi are harmful to the insect host and are known as entomopathogenic fungi. These fungi are classified as Entomophthorales or Hyphoymycetes genera. Under favourable conditions, asexual fungal spores or conidia travel throughout the area in which the insect host is present, resulting in fungal infection and transmission. The spores develop in the blood of the insect, and the growing mycelia progressively kill the host. Fungi that are being employed to manage insects include *Hirsutellathompsonii*, *Nomuraearileyi*, *Verticilliumlecanii*. *Metarhiziumanisopliae*, *Metarhiziumflavoviride*, *Beauveria bassiana*, *Beauveria brongniari*, *Leptolegnia* spp., and*Coelomomyces*spp.

Protozoa and Nematodes: Entomopathogenic protozoa are often host specific and delayed acting, resulting in persistent infections characterised by broad host debilitation. The host consumes them and they germinate in the midgut. Sporoplasm is then discharged, infiltrating target cells and infecting the host massively. *Nosema* spp. and *Vairimorphanecatrix* are the most well-known entomopathogenic protozoa. Among the *Nosema* spp., *Nosema locustae* is marketed for grasshopper and cricket control.

Morever, Entomopathogenic nematodes, mostly from the genera Steinernema and Heterorhabditis, are utilised in situations where chemical pesticides fail, such as in soil, galleries of boring insect pests, or where insecticide resistance has emerged. *Seiternemacarpocapsae*, *S.riobravis*, *S.scapterisci*, *Heterorhabditisbacteriophora*, and *H.megidis* are excellent EPNs against flies, fleas, fungus gnats, coleopterous larvae notably scarabs, cutworms, armyworms, girdlers and wood borers sciaridflies, slugs, *etc*.

2. Phytochemicals:

Phytochemicals or Plant-Incorporated Protectants (PIPs), are naturally occurring bioactive molecules derived from plants or their derivatives. Several classes of PIPs, such as alkaloids, steroids, terpenoids, essential oils, and phenolics, have previously been described for their insecticidal activity in various plants. Plant families such as Myrtaceae, Lamiaceae, Asteraceae, Apiaceae, and Rutaceae are extensively targeted for anti-insect properties against a variety of insect orders. Crop protection applications include mosquito repellent (citronella oil) and pest management fordomestic pests (cockroaches, ants, fleas, etc.), *Varroa* mite control, as aphicides and acaricides (cinnamon oil) and urbaninsect control (eugenol-based products from basil or clove).

3. Biochemicals:

Biochemical pesticides are non-toxic pesticides, comprised of naturally occurring compounds such as plant extracts, fatty acids or pheromones, growth or mating disrupters, and so on.

Botanical Pesticides: Naturally derived compounds from the plantsare easily biodegradable and have no ill-effects on non-target organisms.Pyrethrum from *Chrysanthemum cinerariifolium*vis. (Compositae), rotenone from *Lonchocarpusnicou*or *Derris elliptica*(Leguminosae), nicotine from *Nicotiana tabacum*(Solanaceae) and *Neemand azadirachtin-related tetranortriterpenoids*derived from *Azadirachtaindica* (*Melia azadirachta*), are outstanding among otherexamples. Neo-nicotinoids, a class of synthetic analogues of nicotine that are furtherclassified into three groups namely: Chloronicotinyl compounds(Imidacloprid and Acetamiprid), Thionicotinyl group compounds(Thiomethoxam) and Furanicotinyl group compounds (Dinotefuran).

Insect Growth Regulators: Insect growth regulators (IGRs) or insect morphogenetic agents used in insect pest control, often known as "third generation insecticides," are juvenile hormones (JH) and their analogues. The primary activities of these chemicals result in the suppression or abnormally rapid acceleration of normal insect growth and development. IGRs are classified into two types based on their method of action: Chitin Synthesis Inhibitors and compounds that interfere with insect hormone activity.

ChitinSynthesis Inhibitors includes benzoylphenylurea (diflubenzuron,teflubenzuron, and novaluron),triazine/pyrimidine derivatives (Cyromazine), and buprofezinwhich affects the ability of insects to produce new exoskeletons whenmoulting. A substance interfering

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with the action of insect hormonesincludes Ecdysteroid agonist (chromafenozideand methoxyfenozide), Juvenile hormone analogues (pyriproxyfen and fenoxycarb) and Antijuvenile hormones (Fluoromevalonate and Piperonylbutoxide) that suppressespupation and induces vitellogenesis during the reproductive stage.

Pheromones: Pheromones are a type of semiochemical released by insects and other animals to communicate with other members of the same species. It can be used to monitor populations or in direct pest management tactics such as mass insect capturing, lure-and-kill, mobility studies, exotic pest identification, and mating disruption. Pheromones are employed in monitoring to detect early infestations of invasive or exotic insects such as Mediterranean and Mexican fruit flies, wood boring and bark beetles, or pests with rapidly increasing ranges such as the gypsy moth, pink bollworm, or oriental beetles. These are non-toxic, biodegradable compounds used to modify insect pest behaviour.

Mode of action of biorational pesticides:

Biorationals are not phytotoxic, do not remain in the environment, and are considerably safer to handle; nonetheless, it is recommended to evaluate a novel product by performing an experimental trial before administering it on a broad scale. Because of their selective behaviour, they are quickly targeted by pests and frequently induce instant paralysis or stoppage of insect feeding on crops. The majority of biorational pesticides are nerve poisons that operate on specific target areas in the nervous system of insects. Some pesticides behave similarly to ancient nerve poisons, causing knocking, fast intoxication, loss of coordination, paralysis, and death, and have a greater affinity for insect receptors than mammalian receptors. Other pesticides have an effect on certain systems, like as moulting, metamorphosis, and the insect endocrinology system. Most biorational insecticides have varied modes of action, are effective against different strains of resistant species, have no indication of cross-resistance, have aided in controlling insect pest resistance, and can play an essential part in insecticide resistance management (IRM) techniques.

Biorationals in IPM:

As Rachel Carson mentioned in her classic book *Silent Spring* in the1970s, against a variety of direct and indirect impacts of chemical pesticides to the agricultural production system, Integrated Pest

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Management (IPM) was created to reduce the danger of pests and pesticides. IPM is the combination of all efficient, cost-effective, and environmentally friendly pest control approaches into a unified, adaptable approach to pest management. Fortunately, public awareness of the adverse effects of chemical pesticides on natural resources and the environment, such as pollution, pesticide residues, and pesticide resistance, has forced us to shift our focus to bio pesticides or biorational pesticides. When employed in IPM programmes, biorational pesticides can significantly reduce the usage of conventional pesticides while maintaining crop output. Living organisms (bacteria, viruses, and fungi) that are harmful to the pest of interest are the most widely utilised. However, bio pesticides may account for around 4.2 percent of the entire pesticides industry in India. It is expected that bio pesticides will equalize with synthetics, in terms of market size, between the late 2040s and the early 2050s, but major uncertainties in the rates of uptake, especially in areas like Africa and Southeast Asia, account for a major portion of the flexibility in those projections. Therefore, different methods for the management of pests include cultural, biological and indigenous knowledge systems, the use of resistant varieties, the use of plant extracts, the use of pheromones and the minimal use of chemicals in an IPM system.