New Generation Insecticides: A potential tool for the management of insect pest

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The development of effective, human friendly and environmentally safe pesticides has been a biggest challenge to feed the expanding population of our planet. In the history of insecticide development, trends have changed from organophosphates, carbamates, and synthetic pyrethroids to nicotinic and diamide insecticide. The extensive use of conventional insecticides (oraganochlorines, organophosphates, carbamates and synthetic pyrethroids) has resulted in the development of severe pest resistance to insecticides, pest resurgence, secondary pests out-break, unacceptable pesticide residues, inimical hazard to the users and detrimental effect on environment and non-target organisms. This has led to the search for novel compounds or newer bio-rationals or "low risk" insecticides viz., neonicotinoids, oxadiazines, diamides, tetramic/ tetronic acid derivatives, phenylpyrazoles, pyridine, avermectins, spinosyns, pyrroles, etc. which has now-a-days, because of their unquestionable insect pests controlling properties at minimal doses, high level of selectivity, greater specificity to target pests along with low toxicity to non-target organisms and the environment, supersede many old/conventional compounds.

As per the recent report, a total of 299 pesticides are registered by the CIBRC in India and 46 pesticides are banned. Furthermore, use of another 27 pesticides is in dilemma which includes insecticides like Chlorpyriphos, Carbofuran, Deltamethrin, Monocrotophos, Quinalphos and many more which is under review to be ban in India.

Different group of novel insecticides

Classification of novel insecticides includes the following groups -

1. Insecticides with synthetic origin (Neo-Nicotinoids, Oxadiazines, Phenylpyrazoles, Pyridine Azomethines, Diamides, Pyridine Carboxamid, Formamidines, Nereistoxin, METI etc.)

2. Insecticides derived from soil microorganisms/macrocyclic lactones (Avermectins, Spinosyns and Pyrrole insecticides)

3. Insect growth regulators (Benzylphenylureas, Thiadiazenes and Juvenile hormone mimics)

4. Miscellaneous (Sulfoximines, Butenolides and Mesoionic).

Neonicotinoides

Neonicotinoid	Year	Trade name	Agricultural Uses(Management of specific pests)
Imidacloprid	1991	Admire®, Gaucho®, Merit®, Provado ®	Brown plant hopper, White backed plant hopper and Green leaf hopper in paddy and jassids, aphids and thrips management in okra
Acetamiprid	1995	Assail®, Intruder ®	Jassids and whitefly in cotton and for control of aphids in cotton and cabbage
Thiamethoxam	1998	Cruiser®, Actara®	Hoppers in mango, Whitefly and jassids in cotton and Aphids and thrips in tomato and cotton
Clothianidin	2001	Poncho®	Brown plant hopper in rice and sucking pest complex of cotton
Dinotefuron	2002	Safari®, Venom®	Rice Brown plant hopper and whitefly, jassids, aphids & thrips in cotton

Neonicotinoids are neuro-active insecticides which are synthetic analogues of nicotine. This group has broad insecticidal spectrum, exhibiting systemic and translaminar properties, and high residual activity with unique mode of action. First commercialized neonicotinoid was Imidacloprid in 1991. Insecticide act as Nicotinic acetylcholine receptor (nAChR) competitive modulators as they mimic the

action of neurotransmitter acetylcholine and bind at a specific receptor site on the postsynaptic membrane leading to nerve overstimulation which ultimately leads to paralysis and death of insect within few hours. The major demerit of application of neonicotinoide is toxicity to bees possibly leading to Colony Collapse Disorder.

Oxadiazine

Oxadiazines are a family of voltage dependent sodium channel blockers that act by occluding the sodium channel pore, blocking nerve action potentials and paralyzing insects. Paralysis by sodium channel blockers has been called relaxed paralysis, to distinguish it from the tetanic paralysis caused by many other insecticides. Most promising example of oxadiazine group is Indoxacarb developed by DuPont in 2000 (Avaunt®) which has good field activity against number of lepidoptera pests, specially *Helicoverpa armigera* and DBM, *Plutellla xylostella.*

Phenylpyrazoles

This group of insecticides discovered in 1987 includes GABA-gated chloride channel antagonists that perform by obstructing the chloride channel pore leads to overstimulation and convulsions. They exhibit both herbicidal and insecticidal activities with contact, stomach and systemic action and highly effective against lepidopterous larvae, onion maggots, termites and coleopteran larvae in soil. The major examples under this group are Fipronil (against Diamond Back Moth) and Ethiprole (against Sugarcane Borers).

Pyridine Azomethines

They are the selective homopteran feeding blockers effective against aphids, cicadas, whiteflies and leafhoppers. It includes insecticides like Pymetrozine (Chess®, Plenum®, Fulfill®) developed in 1999 by Novartis (now Syngenta).

Diamides

These insecticides activate ryanodine receptors, which are calcium-activated channels in the sarcoplasmic reticulum of muscle cells. The diamides bind to the ryanodine receptors and cause the calcium channels to remain partially open and causing sustained muscle contractions leading to rapid feeding cessation, regurgitation, lethargy and tetany (sustained contraction of muscles).

Pyridine Carboxamid

The classical member of this class of insecticide is Flonicamid which is systemic as well as translaminar in nature and provides long term control against aphid, thrips, whitefly, planthopper, plant bugs by its antifeedant effect due to action of the compounds on chordotonal organs, proprioceptive sensory organs. It is commercially available as Ulala®.

Formamidine

These group of insecticides (Amitraz) were introduced in 1975 and are primarily responsible to manage ticks, lice and mites on domestic animals and also to control psyllids, whiteflies and mites on certain crops by acting specifically on the octopamine receptor agonists which triggers many excitatory effects related to fight-or-flight which results in tremors and convulsions, as well as suppression of feeding.

Tetronic Acid Derivatives

Tetronic acid derivative insecticides are inhibitors of Acetyl CoA Carboxylase, the principal enzyme involved in the catalysis of fatty acid biosynthesis and exposure to these insecticides inhibits lipid biosynthesis, halting the development of immature insects, including whitefly pupae, which are not controlled by many other insecticides. Adults are not acutely affected, but it alters the fecundity. Some basic members of the group include-

a) Spirodiclofen- the first product in this group, was introduced in 2003 as a selective acaricide on citrus, grapevines and pome fruits. Trade name - Envidor® 24% SC.

b) Spiromesifen- introduced in 2005, controls whiteflies in addition to mites. Trade name - Oberon® 22.9% SC.

c) Spirotetramat- introduced in 2008, is systemic and controls aphids, scales, mealybugs, psylla, phylloxera and thrips, as well as mites and whiteflies. Trade name- Movento® 15.31% OD.

Thiourea Derivatives

Diafenthiuron is the representative molecule of this group that is known for inhibiting mitochondrial

ATP synthesis i.e. oxidative phosphorylation and are effective for the management of white flies, aphids, thrips and jassids in cotton, diamond back moth in cabbage and red spider mites of citrus and chilli.

Nereistoxin Analogues

These compounds are known as thiocarbamate insecticides or analogs of nereistoxin, a natural toxin of the marine worm Lumbriconereis heteropoda. This class includes Thiocyclam, Cartap, Bensultap, and Monosultap. Cartap hydrochloride is used for controlling Colorado potato beetles, diamondback moths, rice stem borers, and thrips on rice and vegetables as nicotinic acetylcholine receptor channel blockers.

METI Insecticides

As the name suggests they act by mitochondrial complex I electron transport inhibitors. This group contains insecticides like fenazaquin, fenpyroximate, pyridaben and tolfenpyrad used to control leafhoppers, mites and whiteflies in fruit crops, vegetables, ornamentals, nuts and cotton.

Insecticides derived from soil microorganisms / macrocyclic lactones

Avermectin

Avermectin is broad spectrums chemical that are obtained through fermentation of microorganism *Streptomyces avermitilis* isolated from soil that have contact as well as stomach poison to mites and insects. They kill the target organism by increasing flow of chloride ions into cells by binding to GABA-gated chloride channels receptor of insect nervous system.

Table 2: Agricultural uses of avermectins as recommended by CIBRC Report 2021

Crop Common	Name of the pest
Abamectin 01.90% EC	
Rose (Ornamental)	Red spider mites (*Tetranychus urticae*)
Grapes	Mites
Emamectin benzoate 05.00% SG	
Cotton Boll worms	Cabbage Diamond back moth
Red gram (Arhar/Tur)	Pod borer
Emamectin benzoate 01.90% EC	
Cotton	Boll worms
Chilli	Fruit borer, Thrips
Paddy	Leaf folder & hispa

Spinosyns: These bioinsecticides derived from macrocyclic lactones produced by soil actinomycete, *Saccharopolyspora spinosa* through fermentation. These classes of insecticides are effective for controlling lepidopteran, thysanopteran and dipteran pest that act as nicotinic acetylcholine receptor (nAChR) allosteric modulators, leading to nervous system hyperexcitation and contractive paralysis.

nsect growth regulators: Insect growth regulators (IGRs) are the compounds that alter the normal growth of insects by interfering with insect metamorphosis, embryogenesis or reproduction. IGRs are mainly classified into chitin synthesis inhibitors and Juvenile hormone analogues.

Methoprene was the first juvenile hormone analogue in 1970 marketed in the US. Other examples include Hydroprene, Kinoprene, Fenoxycarb and Pyriproxifen etc. They are used as household insecticides. Chitin synthesis inhibitors are another important IGRs. It comprises benzoyl phenyl urea (diflubenzuron, triflumuron, teflubenzuron, hexaflumuron and novaluron), triazine/ pyrimidine derivatives (Cyromazine, Dicyclanil), and buprofezin. They effect the production of new exoskeletons at the time of moulting. These substances are mainly interference with the pupation and induce the vitellogenesis at the time of the reproductive stage of the insect.

Miscellaneous: They all act as nicotinic acetylcholine receptor (nAChR) competitive modulators.

Sulfoximines

It includes insecticides with broad spectrum activity against key sap feeding pests and control of many imidacloprid-resistant insects.

Butenolides

Butenolides are the class of systemic insecticide lactones with a four-carbon heterocyclic ring structure intended for controlling sucking pest such as aphids, hoppers and whiteflies. It includes Flupyradifurone.

Mesoionics

This group includes synthetic compounds like Triflumezopyrim which is effective against BPH in rice.

Conclusion

These new generation insecticides are need of the hour and the development strategy for creating new pesticides, which includes the basic three agendas i.e. development of pesticides that are effective at an extremely low dosage, development of pesticides that are readily degradable and less residual in the environment and development of selective toxic agrochemicals. New generation insecticides often have diverse modes of action, targeting specific biochemical pathways in insects. This helps in reducing the development of resistance among pest populations. While new generation insecticides offer promising solutions, it's crucial to consider their potential impact on human health, non-target organisms, and the environment. Sustainable pest management practices that integrate various approaches, including biological control, cultural practices, and judicious use of chemicals, are essential for long-term success.

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