INTERNATIONAL RESEARCH JOURNAL OF PHARMACY

www.irjponline.com

ISSN 2230 – 8407

Review Article

A REVIEW ON COMPARATIVE ANALYTICAL APPROACH TOWARDS CHEMICAL PESTICIDES TO BIO PESTICIDES

Sarika Chaturvedi and Shikha Khandelwal *
Amity Institute of Biotechnology, Amity University Haryana, Gurgaon, India
*Corresponding Author Email: writein.shikha@gmail.com

Article Received on: 03/05/19 Approved for publication: 15/07/19

DOI: 10.7897/2230-8407.1009254

ABSTRACT

The inappropriate and excessive use of agricultural pesticides now a day creating a major impact on the environment including human health causing contamination of soils, agricultural crops and groundwater. Chemical insecticides such as organochlorines, organophosphates, carbamates, pyrethroids, triazines are very important and effective in modern crop management but they pose serious threats to the human health, wildlife, natural environment and economic benefits. Therefore, the need to feed an ever-increasing global population combined with increasing demand for sustainable agricultural practices has geared a significant increase in demand for bio pesticides. Bio pesticides have various advantages over the chemical ones, most importantly they are found to be more cost effective make environment healthy. In this paper, the various chemical pesticides and bio pesticides are listed and application of bio pesticides as a safe pesticide used to control the pest in order to maintain the sustainability in the agricultural production was discussed. The paper has also described the transition of chemical pesticides to bio pesticides and their consumption demand in the Indian market across the states.

Keywords: Bio pesticides, Chemical, Environment, Fungicides, Herbicides, Synthetic

INTRODUCTION

The population of the world is estimated to approx. 10 billion by 2050 according to the United Nations. Therefore, the production of food will also increase by 70% and this will increase the demand to produce and sell more[1]. India is considered to be largest agrarian economy and has millions of people which are dependent on farming and its allied activities for a living. The bio technological advances, globalization, and international trade have all further increased the need to have more farm production in the country. Agriculture plays important role in growing population, food safety and health prospect with respect to use of pesticides and its resistance, depletion of the natural environment and dramatic change in the climate[1]. Also, it has been demarcated that excessive use of the chemical pesticides results in negative impacts on human health, wildlife, natural environment and economic benefits. Now days, in agriculture farming, the long-established methods of farming method are being established where synthetic and chemical pesticides are replaced with organic and natural pesticides which in result leads to increasing yield and make ecofriendly environment. This new concepts of using organic pesticides are emerging greatly but there is a very little knowledge on the sources to obtain the same.

This review is highlighting a new concept in agriculture which involves a substantial move from chemical pesticides towards organic pesticides that included bio pesticides and compounds. Recent findings related to health impact have been mainly associated with the use of synthetic and chemical pesticides, such as organochlorines, organophosphates, carbamates. But the use of organic pesticides is found to be safer and more ecofriendly[2]. The major impact on the health defines the urgent requirement of unconventional solutions which should be executed in agricultural approach for targeting sustainable development.

Overview on Pesticides

Pesticide refers to any substance used to control pests. The suffix –*cide* is Latin for killer (pesticide means killer of pests). It is also defined as these are substances or mixtures of substances that are used to protect plants from pests or weeds and humans from malaria, dengue fever, and schistosomiasis etc. Most pesticides are found to be associated with environmental and health related issues. In fact, the use of some pesticides has been banned in agricultural practices. There are various parameters which determine the quality and use of pesticides such as type, duration and route of exposure of pesticide. Pesticides is known to be causing various human health related diseases like skin, olfactory, reproductive and intestinal diseases etc because of its accumulation in human and animal body fat. The reason may be due to regular uptake of pesticides residues in our everyday diet. Also, the proper cleaning of food items cannot completely remove the traces of pesticide residues[2]. They have also been identified in human breast milk samples, which is major concern for children health[3]. Firstly in 1962, famous scientist Rachel Carson published the risks associated to DDT (dichlorodiphenyltrichloroethane). Then US authorities also mentioned the cancelation of the pesticides for agricultural uses followed by 1983 EDB (ethylene dibromide) and methyl bromide in 2005. According to NAS, 1987 a certain fraction is carcinogenic as 18% of all insecticides and 90% fungicides were carcinogenic.

Therefore, there is the need of bio pesticides or bio active compounds.

Pesticides can be classified by

- Target organism (e.g., herbicides, insecticides, fungicides, rodenticides, and pediculicides),
- Chemical structure (e.g., organic, inorganic, synthetic, or biological (bio pesticide),
- Physical state (e.g. gaseous (fumigant),
- Bio pesticides include microbial pesticides and biochemical pesticides.

Another classification of pesticides that are based on a routine basis natural, synthetic, (inorganic, organic) and chemical

Natural Pesticides

Natural pesticides occur in nature. These are environmentally friendly, healthier or safer. e. g. pyrethrin insecticide extracted from *Chrysanthemum* plants and *Azadirachtin*, an extract from the neem tree.

Synthetic Pesticides

Synthetic pesticides are manmade and an inorganic fertilizer, not having the elemental carbon(C) e. g. Ammonium nitrate (NH_4NO_3), potassium chloride (KCl), sodium phosphate (Na_3PO_4), calcium sulfate ($CaSO_4$).

Inorganic insecticides

It comprises of mineral origin and elemental sulphur. This included arsenate and fluorine compounds. As acaricides contain sulphur and rodenticides contains phosphorus.

Organic insecticides

That contains carbon and are different types as nerelstoxin isolated from annelids, Nicotinoids, pyrethroids, isolated from plants, organochlorines, organophosphorus and carbamate as synthetic organic insecticides

Chemical Pesticides

These are not beneficial to our health and garden health. Chemical as insecticides, fungicides, herbicides, rodenticides, and plant growth regulators are typical examples (Figure 1)

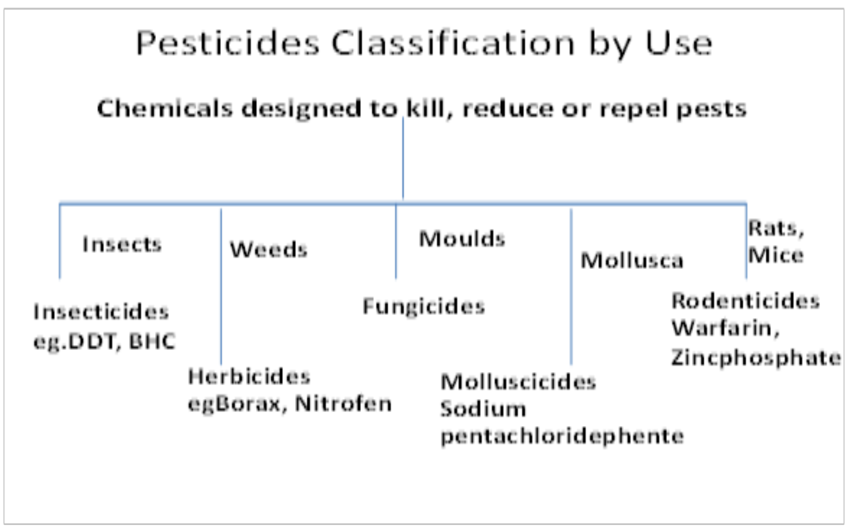

Figure 1: Classification based on killing the organisms

Another classification is based on the chemical composition (Table 1)

The World Health Organization worked on rats and other laboratory animals and classified pesticides on the basis of their toxicity, administering oral/dermal and estimating the median lethal dose (LD_{50} (mg/kg) that produces death in 50% of exposed animals[4].

Class IA	Extremely dangerous/extremely toxic, estimated respective lethal dose (LD_{50} mg/kg body weight<5) eg. Parathion, Dieldrin
Class IB	Highly dangerous/highly toxic (LD_{50} mg/kg body weight 5-50) eg. Eldrin, Dichlorvos
Class II	Moderately hazardous/moderately toxic (LD_{50} mg/kg body weight 50-2000) eg. DDT, Chlordane
Class III	Slightly hazardous/slightly toxic) (LD_{50} mg/kg body weight over 2000) eg. Malathion.
Class U	Unlikely to present acute hazard (LD_{50} mg/kg body weight 5000 or higher) eg. Cycloprothrin, carbetamide

Bioactive compounds (such as phosphinothricin, azadirachtin, and spinosad) are supposed to be source of new pesticides which are derived from microbial, plant, or other natural sources having reduced risk to the environment and a high potential for use in modern integrated pest management strategies. It is also noted that in comparison to reference synthetic pesticides glyphosate and tebufenozide, we find no evidence to support the hypothesis that natural products pose inherently lower risk to the environment than these synthetic pesticides. Even we need to investigate the individual components and study their interactions among different species that are sometimes used together. In the literature there are some preparations like arrow poison which involve mixing of seven different species. So we have to focus on how each plant changes and amplifies the toxicity of poison.

Table 1: Pesticides on the basis of chemical structure are classified into different groups as

Types of Chemical pesticides	Properties and example	Health Impact	References
Insecticides			
Organochlorine	Stable, too persistent, used in preservation and cultivation of grapes, lettuce, tomato, alfalfa, rice, sorghum, cotton, wood eg. Dichlorodiphenyltrichloroethane (DDT), p,p-dichlorodiphenyldichloroethylene (DDE), Dieldrin, Endosulfan, Heptachlor, Dicofol, Methoxychlor, Lindane, Endosulfan	Endocrine and embryonic development disorder Carcinogenic. Directly contact with central nervous system. *In utero* exposure associated with neurodevelopmental effects in children. disorder, Hepatic and hematological disorder, seizures and acute poisoning death.	5, 6, 7, 8, 9
Organophosphorus	Most common and widely used, phosphoric acid derivatives, alkylating properties used as herbicide, insecticides and matricidesin vegetable crops, fruit trees, grains, cotton, sugarcane.eg. Glyphosate, Thiophos, Malathion, Parathion, Dimethoate, Clorpyriphos, Diazinon, Azinphos	Endocrine and neurological disruptors. Decrease in insulin secretion and testosterone. Induces necrosis, apoptosis, mutation, dementia, cancer. Nervous problems, cardiovascular diseases, Dysfunction of cholinesterase, Prenatal exposure causes decreased gestational duration. Hypertension, diabetes, strokes, autism, kidney failure, Parkinson's and Alzheimer's diseases	10,11,12,13,14,15,16,17
Carbamate	Acids or Dimethyl N-methyl carbamic acid derivatives of esters. Used as fungicides, insecticides, herbicides, nematicides. e.g. Carbaryl, carbin, Aldicarb, Carbofuran, Ziram	Endocrine-disrupting and reproductive disorders Mitochondrial dysfunction, Neurobehavioral effects, Cytotoxic and genotoxic effects in hamster ovarian cells, induce apoptosis and necrosis Human natural killer cells and T lymphocytes. Dementia and non-Hodgkin's lymphoma Dioxin toxicity by inhibiting a transcription factor	13,18,19,20,21,22,23
Synthetic pyrethroids	Pyrethrum extract derived from chrysanthemum flowers (pyrethrins) eg. Fenvalerate (Type II), Permethrin (Type I), Sumithrin, Allethrin (Type I), Tetramethrin (Type I), Deltamethrin (Type II),Cypermethrin (Type II)	Endocrine-disrupting activity and affecting reproductive behavior, DNA damages in human sperm, Developmental neurotoxicity and neuronal hyperexcitaion.	24,25,26
Neonicotinoid	eg. Iimidacloprid, Thiacloprid, and Guadipyr	Increase aromatase expression which is engaged in breast cancer and important role during developmental periods.	27
Herbicides			
Triazines	Atrazine (commonly used), Simazine and Ametryn	Endocrine-disrupting effects Reproductive toxicity and delays in sexual maturation, oxidative stress, cytotoxicity and dopaminergic effects .	28,29,30
Bipyridyls	Paraquat, Glufosinate, Diquat	Acute respiratory distress syndrome pulmonary edema, convulsions, cardiac, renal, and hepatic failure	31,32
Chlorophenoxy	2,4-dichlorophenoxyacetic acid (2,4-D) 2,4,5-trichlorophenoxy acetic acid (2,4,5-T)],	Non-Hodgkin's lymphoma, Lymphoid cancer in humans, Hormone-disrupting activity Disrupt neurotransmitters dopamine and serotonin	33,34
Dinitrophenols	Dinitroorthocresol	Erythema and oedema, Skin and eye irritation; skin sensitization	35
Fungicides			
Thiocarbamates, Dithiocarbamates	Thiram, Ziram, Zineb, Maneb, Mancozeb	Allergic contact dermatitis and photo dermatitis, scratchy throat, Reproductive and birth defects in animals	36
Cupric salts	Copper sulfate, Cupric nitrate, Copper(II) oxychloride, Cuprous chloride	Anemia, Inflammation of the gastrointestinal tract Teratogenic, Mutagenic, Carcinogenic Effects	37,38
Thiabendazoles	Tiabendazole, Mintezol, Equizole	Carcinogenic, Vision impairment and psychic alterations, Hepatobiliary toxicity, Psychic alterations	39
Triazoles	Hitertanol, Hexaconazole, Penconazole, Tebuconazole Uniconazole Cyproconazole	Endocrine disruptors and inhibition of cytochrome P450 (CYP450), Teratogenic, Nervous, immune, and reproductive disorder	40,41

Dicarboximides	Iprodione, Vinclozolin, Procymidone	Reproductive toxicity in males, Damage to unborn child Harmful if inhaled	42
Anilinopyrimidine	Pyrimethanil, Mepanipyrim, Cyprodinil Pyrimethanii	Thyroid tumors in rodents, Histopathological changes in liver and thyroid	43
Rodenticides			
Warfarines Brodifacoum	Coumadin; Coumafene; Zoocoumarin Anticoagulant rodenticide, Therapeutic anticoagulant	Deep-vein thrombosis and pulmonary embolism, Willebrand disease, platelet deficiencies, and canine ehrlichiosis	44
Fumigants			
Aluminium and Zinc phosphide	Solid, toxic to all stages of insects, highly potent, not affect seed viability, free from toxic residues eg. Celphos, Quickphos, Synfume and Phosfume	Irritability, anxiety, dizziness, ataxia, numbness, paraesthesia, hypoxia or hypotension , Delirium, seizure, and coma	44
Methyl bromide	Colorless highly toxic volatile liquid or a gas insecticide, a rodenticide, a fumigant, a nematocide and as a fire extinguishing agent	Ataxia, paralysis, central nervous system (CNS) depression, apathy, retardation of speech and movement	45
Ethylene dibromide	EDB, glycol dibromide, Bromofume, Dowfume W 85	Damage to the liver, stomach, adrenal glands, respiratory, nervous, liver, heart, and kidneys; cancer	46
Insect Repellents			
Diethyltoluamide	Benzamide, diethyl toluamide Diethyl-m-toluamide Diethyltoluamide**,** Diethyltoluamidum	Epidermal reactions, breathing difficulty, burning eyes, headaches	47

I. Bio Pesticides

Bio pesticides are made from naturally occurring living organisms (e.g., bacteria, fungi, and viruses), their products (biochemical produced by them) and plant byproducts. They have toxic effects on harmful pests and are supposed to be harmless, eco-friendly, target specific, biodegradable, cheap, healthier and safer. There are currently 1,401 products that are registered as biopesticides in April 2016. They contain up to 299 natural active ingredients.

Types of Bio pesticides

Bio pesticides are classified into three different categories:

1. Biochemical pesticides (herbal-based substances)
2. Microbial pesticides ((bacteria, fungi or virus) and
3. Plant-incorporated protectants (genetically modified materials).

1. Biochemical pesticides

These are natural pesticide that utilizes naturally occurring substances instead of chemicals to control pests. They are made from non-synthetic substances such as baking soda, diatomaceous earth (DE), canola oil, neem oil, tea tree oil, cayenne pepper, and other compounds. They are interfering with pests in mating as sex pheromones and various scented plant extracts that attract insect pests to traps to kill the pests.

2. Microbial bio pesticides

These are pest specific means do not target non-pest species and environmentally benign. These are the largest group of broad-spectrum bio pesticides. Microbial pesticides can control many different kinds of pests, although each separate active ingredient is relatively specific for its target pest (Figure 2)[48].

Bacterial Bio pesticides are divided into four groups

I. Crystalliferous spore formers (as *Bacillus thuringiensis* and *B. sphaericus*)
II. Obligate pathogens (as *Bacillus popilliae*)
III. Potential pathogens (as *Serratiamarcesens*) and
IV. Facultative pathogens (as *Pseudomonas aeruginosa*)

Among them spore formers have been most widely used commercially due to their safety and effectiveness. *B thuringiensis* is effectively used as insecticides[49]. The insecticide property is due to Cry family of crystalline proteins that are produced in the parasporal crystals and are encoded by the cry genes. Some common commercial products based on *B thuringiensis* are available globally as Bactimos, Florbac, BTI granules, Ecotech Pro, Novodor. Other species of bacteria as *Agrobacterium radiobacter, Bacillus popilliae, B. subtilis, Pseudomonas cepacia, P. chlororaphis, P. flourescens, P. solanacearum* and *P. syringae* also used for pest management and also available commercially.

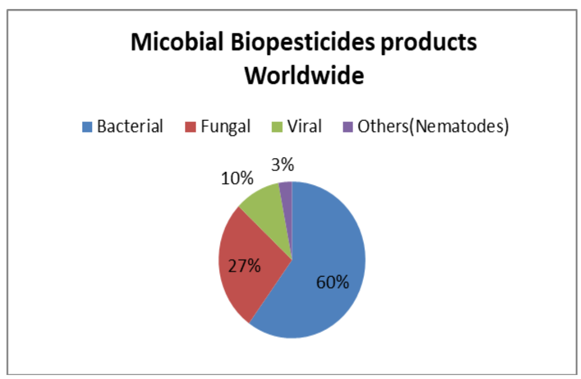

Figure 2: Worldwide Microbial Biopesticides[48]

Viral Bio pesticides

Microbial viral insecticides are pathogens that attack insects and other arthropods. Baculoviruses are arthropod viruses used as biological control of pests in agriculture and forestry. Some other viruses have been commercialized for use as bio pesticides Capex, Dispavirus Lecontvirus WP, Virtuss WP TM, Biocontrol-1, Rootshield Drench WP (27115) Rootshield Granules, Carposin, Granupom, Madex3, Virin-EKS, Virin-GYAP, Carpovirusine, Nutguard-V, AfMNVP, Multigen, Polygen, VFN80, Gusano, Otienem-S, and Spod-X LC (Figure 3)[49,50].

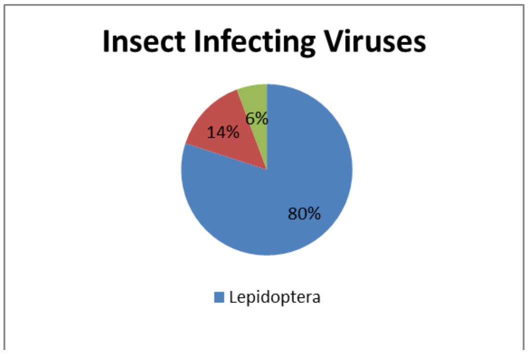

Figure 3: Insect infecting Viruse[50]

3. **Plant-Incorporated-Protectants** (PIPs)

   These are substances that plants produce from genetic material that has been added to the plant as the gene for the pesticidal protein and that can be introduce into the plant's own genetic material.

Table 2: Natural Pesticides with their sources and health impacts

Names of Natural pesticides	Source Organism	Crop	Health Impact	References
Pheromones	Insects	Oilseed Crops	Disrupt mating behavior and control insect populations	51
Methyl carbamate insecticides	*Physostigma venenosum*	control of cockroaches and other household insects in restaurants, kitchens and homes	Endocrine-active factors, Stressors	52
Pyrethrin insecticide	*Chrysanthemum cinerariaefolium*, first discovered plant by African Tribal peoples	Fruit, crops and ornamentals and vines	Work on voltage-sensitive sodium channels control insect pests	53
Cube resin (Rotenone) organic pesticide.	Active ingredients deguelin, rotenolone, and tephrosin are also present in rotenone products. *Derris* or *Lonchocarpusutilis* and *Lonchocarpusurucu* (Leguminosae)	Vegetables, berries, tree fruit, nuts, forage crops and sugarcane	Control insect pests	54
Margosom (Azadirachtin A, Bio insecticide) and Neem Oil and	*Azadiractaindica* (Neem Tree)	Cotton, Rice, Tea, Tomato, Brinjal, Okra, cabbage	Potent insect antifeedant block the synthesis and release of molting hormones (ecdysteroids)	55
VeratrineSabadilla based products (organic insecticide)	(Main compounds alkaloids cevadine and veratridine) *Schoenocaulon officinale* (sabadilla lily)	Vegetables effective against caterpillars, leaf hoppers, thrips, stink bugs and squash bugs.	Work on voltage-sensitive sodium channels	56
Nicotine	*Nicotianatabacum*, *N. glauca or N. rustica*	Medicinal crops	Control crop insect pathogens	57
Capsaicin	Hot chili peppers (*Capsicum frutescens*)	Vegetable crops, flowers, ornamental plants,	control crop insect pathogens	58
Toxic compound	Piquiá *(Caryocar*spp)	Ornamentals crops	Toxic to the dreaded leaf-cutter ant (*Atta* spp.).	59
Anosom (*Annonaceousacetogenins*),	*Annona squamosa* ((Custard Apple)	Soybean crops	Targets on *Helicoverpaarimigera, Helicoverpazea, Spodopteralitura, Spodopteraexigua, Earias spp., Achaea janata, Nephotettixvirescens*, Bunch caterpillar, Green Leaf Hopper, Leaf Folder, Army worm, Cut Worm.	60
Derisom (Karanjin)	*Pongamiaglabra* (Karanj tree)	Cardamom, chillies, Cotton, vegetables, cereals, millets, pulses, oilseeds, fibre and sugar crops, plantation crops, fruits, spices	Controls mites , scales ,thrips and other sucking pests It controls mites like red spider mites, scarlet mites, yellow mites, purple mites and other types of mites	61
Milky Spore	*Paenibacillus popilliae*	Lawn and garden in grasses	Control Japanese beetle larvae, or grub worms	62

Avermectins (Abamectin)	(mixture of >80% avermectin B1a and <20% avermectin B1b) *Streptomyces avermitilis* (soil bacterium)	Ornamental plants, citrus, cotton, pears and vegetable crops to control phytophagous mites	Useful in glutamate and GABA gated chloride-channel opening	63,64
Milbemycins	(mixture of ≥70% milbemycin A4 and ≤30% milbemycin A3) *Streptomyces sp*. culture broths	Fruit, vegetables and ornamentals plants	Useful in glutamate and GABA gated chloride-channel opening	64
Spinosad (Organic insecticide)	(Mixture of spinosyn A and spinosyn D) *Saccharopolyspora spinosa* (Actinomycete bacteria)	Agricultural crops and ornamental plant	Used on cotton and turf grass. Also used for the control of a very wide range of caterpillars, leaf miners, thrips and foliage-feeding beetles.	65,66
Glufosinate herbicide	Racemic mixture of L-phosphinothricin (butanoic acid, 2-amino-4-(hydroxymethylphosphinyl), (2S)-)and D-phosphinothricin) *S. viridochromogenes*	Annual and perennial broadleaf weeds and grasses	L-phosphinothricin inhibitor of glutamine synthetase (GS) is produced by the soil microbe *Streptomyces hygroscopicus.*	67
Tripeptide bialaphos (Protoxin)	4-[hydroxy(methyl) phosphinoyl]-L-homoalanyl-L-alanyl-L-alanine) *Streptomyces hygroscopicus*	Morning glories, hemp (*Sesbaniabispinosa*), Pennsylvania smartweed (*Polygonumpensylvanicum*) and yellow nutsedge	Natural GS inhibitors, Used for weed control in Japan.	67
AAL-toxin	Close analog of the *fumonisin mycotoxins*	Broadleaf plants (e.g. jimsonweed, prickly sida and black nightshade)	Highly toxic Used to kill weed species. Highly toxic to mammals by inhibition of ceramide synthase	68
Phosphionthricin (herbicide)	2-methylphosphinico-ethanoic acid phosphinothricin-*N*-acetyltransferase	Dicot crops, such as like tobacco, tomato, spring and winter rapeseed, alfalfa, and several horticultural crops	Microbial toxin	67
Bti (crystalline proteins), Insecticide	*Bacillus thuringiensis* and *Bacillus sphaericus* 2362 (*Bs*)	Cabbage and Cauliflower	Effective against mosquito and other dipteran larvae black fly (simuliidae), and fungus gnats	69
Bti (crystalline proteins), Insecticide	*B. thuringiensis* ssp. *Kurstakiandaizawai*,	Soyabean Castor, Tobacco	Act as insecticides against lepidopteran larval species	70
Bti (crystalline proteins), Insecticide	*B. thuringiensis tenebrionis*	Tomato, Chilies, Rice Red gram,	Activity against coleopteran adults and larvae, most notably the Colorado potato beetle (*Leptinotarsadecemlineata)*	70
Bti (crystalline proteins), Insecticide	*B. thuringiensis japonensis* strain Buibui	Cotton	Activity against soil-inhabiting beetles	70
Bs, Bactericide	*Bacillus subtilis*	Banana Sigatoka (caused by *Mycosphaerellamusicola*) Paddy (Bacterial leaf blight)	Bacterial and Fungal Pathogens such as *Rhizoctonia, Fusarium, Aspergillus*, and others	70
Pseudomonas fluorescens, Fungicide/ Bactericide	*Pseudomonas fluorescens,*	Wheat (Loose Smut) Paddy (Bacterial leaf blight) Ground nut (Late leaf spot) Rice (Leaf and neck blast) Chili seedlings (Damping off) Tomato (Wilt)	Several fungal, viral, and bacterial diseases such as frost forming bacteria	71
Metrahiziumani sopliae	Entomopathogenic fungus	Cabbage, Canola (*Brassica napus* L.)	Insect pest control, used as a biocontrol agent, particularly for malaria vector species	72
Cryptolaemusm ontrouzieri	Ladybird beetle	Citrus, coffee, grapes and several other fruit crops and ornamental	To control mealy bugs especially in fruits	73
Helicoverpaarmigera (Hubner) and *Spodopteralitura(Fabricius)*	Insecticide	*Colocasiaesculenta* cotton, flax, groundnuts, jute, maize, soya beans, tea, tobacco, vegetables, lucerne	Used against bollworms in cotton and pod borers species specific for Lepidoptera , Hymenoptera and Diptera	74
Phromone lures for Helicoverpaarmigera	Insecticides	Tomato, Potato: *Spodopteralitura* , Cabbage: *Brassica oleracea* , Brinjal,	To trap productive male of gram borer and tobacco caterpillar	74

(Hubner) and *Spodopteralitur**a***				
Trichoderma viride/harzanum	Fungicide	Paddy (Foot rot)	Control root rot and wilt diseases especially on pulses	75
Trichoderma spp. (egg parasite)	stingless wasp	Cardamom (Capsule rot) Tomato, Brinjal, Okra (Wilt) Carrot, Maize, Pigeon pea Pulses (Root rot)	Used for control of sugarcane, early shoot borer, cotton bollworms, sorghum stem borer	75
Muscodoralbus Fumigant	Fungus originally isolated from the bark of a cinnamon tree in Honduras.	Vegetable crops bean potato pepper	Bacteria and soil-borne pests	76
Fungicide	*Aspergillus flavus* strain AF36	Pistachio Orchards	fungicide for cotton	76
Pyrethrum (World trade in daisy flowers, , oleoresin, insecticide)	Mixtures of pyrethrin esters (atleast six) (pyrethrins, chrysanthemates and pyrethrates) dried flowers of *Tanacetumcinerariaefolium* (Asteraceae)	Crops and ornamental plants	Fast acting and toxic to insects at very low doses, as well as degrading quickly in the environment due to its instability toward heat, light, and air.	77
A forest vine *Lonchocarpus*	Insecticidal, acaricidal, and other pesticidal properties	To control parasitic mites on chicken, fowl, lice, ticks on dogs, cats, and horses.	Poison to stun fish the roots of this plant gives rotenone, a biodegradable pesticide.	78
Leptospermone	bottlebrush plant	To reduce infestation of Drosophila suzukii in berry crops	Inhibitor of hydroxyl phenylpyruvate dioxygenase (HPPD)	79
Strobilurin	Basidiomyces growing on decaying wood	Cereals and soybeans	inhibit respiration at the complex III: cytochrome bc1 site	80
Cinnamaldehyde	*Pleuropterus Ciliinervis*	Potential action against various bacteria (*Pseudomonas aeruginosa, Staphylococcus aureus,* and *Escherichia coli*) and yeast (*Torulopsisutilis, Schizosaccharomycespombe, Candida albicans,* and *Saccharomyces cerevisiae*)	Inhibit formation of fungal cell wall by inhibiting chitin synthesis.	81

Transition from Synthetic to Natural Pesticides

Now with the change in time where agricultural sector/industry is moving from use of the synthetic to natural pesticides due to the major impact of chemicals on the human health, wildlife and environment. An approach is required to reduce the use of synthetic chemicals and implementation of environmentally safe natural and friendly practices. As both synthetic and natural pests equally contribute in controlling the pest but their mode of action is different (Table 3)[82].

Table 3: Chemical vs Bio Pesticides

Bio Pesticides	Chemical Pesticides
Naturally occurring bioactive organisms or substance	These are synthetic chemicals (Agrochemicals)
Directly or indirectly with reproduction or simply repelling pests	Work by directly killing or inactivating pests
Slow response by suppressing pest so it takes time.	Quick response for killing the pests.
Less toxic than chemical	More toxic than natural
Narrow spectrum products mean very specific to the target pest	Broad spectrum products mean kills a population of organisms
Decompose very fast	Generally not decomposed
Never negatively impact on the non-harmful species	Negatively impact on the non-harmful species.
Pest never develop resistance	Pest eventually develop resistance
Don’t cause pollution	Cause pollution
Relatively cheaper	Expensive
Growing market preference	Diminishing market
Biopesticides involve maintaining microbial viability during storage and have very specific application requirements	It’s not required
Advances in formulation are extending storage shelf-life and compatibility of mixed products	Shelf life is high
Need training to use biopesticides effectively as different products will need to control different kind of pests and pathogens	Result in management failure through pest resurgence, secondary pest problems or the development of heritable resistance
No health issues	Caused serious health problems due to inadequate controls during manufacture, handling and application.

Current Scenario of Indian Pesticides Market Segmentation by consumption in volume by Chemical and Bio Pesticides

As we know, the overall pesticide market (production and consumption) has been largely dominated by the share of chemical pesticides while bio pesticides form only a small portion of the market due to lack of innovative advancements in research and policies in India. However, in India, per capita consumption of pesticides is among the lowest in the world at 0.6 kg/ ha compared to 13 kg/ ha in China and 7 kg/ ha in USA. India is currently the second largest manufacturer of pesticides in Asia, after Japan in 2012 but in 2015 it became the fourth largest global producer after the US, Japan and China (Figure 4).

The Indian pesticides industry has now been growing at 8-9% p.a. over the past five years. Industry size is estimated to be USD 3.8 billion (INR 21,000 CR) in Financial Year (FY) FY12, USD 4.25 billion in FY14, USD 4.4 billion in FY15 and is expected to grow at 7.5% per annum to reach USD 6.3 billion by FY20 with domestic demand grow at 6.5% per annum and export demand at 9% p.a[83].

In every year from FY11to FY 16, as per the data of ministry of agriculture and farmers welfare, Government of India, there seems to be increase in the demand of Bio pesticides (Figure 5). With respect to crop protection market, out of the total pesticides available in Indian market, in FY2012, 65% of the total is dominated by insecticides, followed by 16% of Herbicides of the total market whereas in FY 2015, Insecticides shared reduction of 5% of the total market share with addition of bio pesticides as 3% of the total market share (Figure 6)[83].

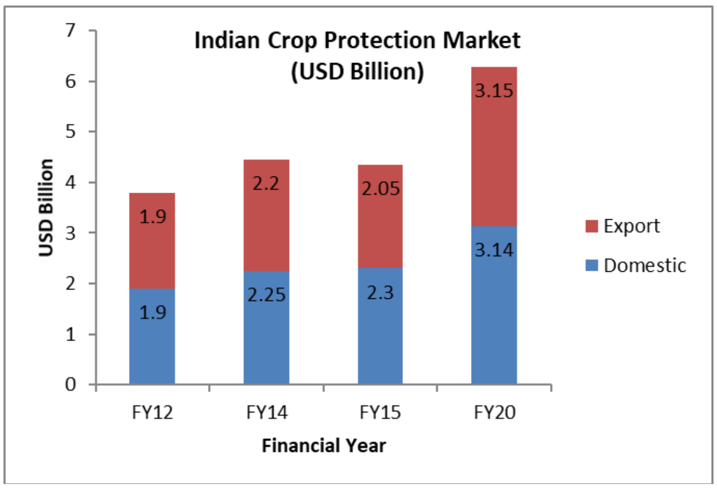

Figure 4: Data represent Indian crop protection market (Source: FICCI)

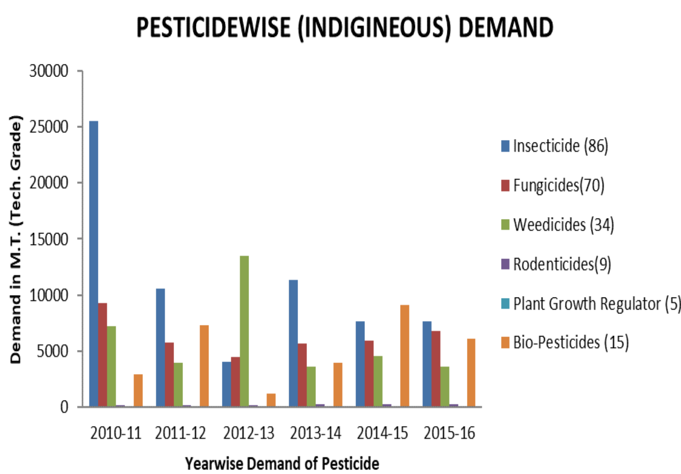

Figure 5: Source: States/UTs Zonal Conferences on Inputs (Plant Protection)

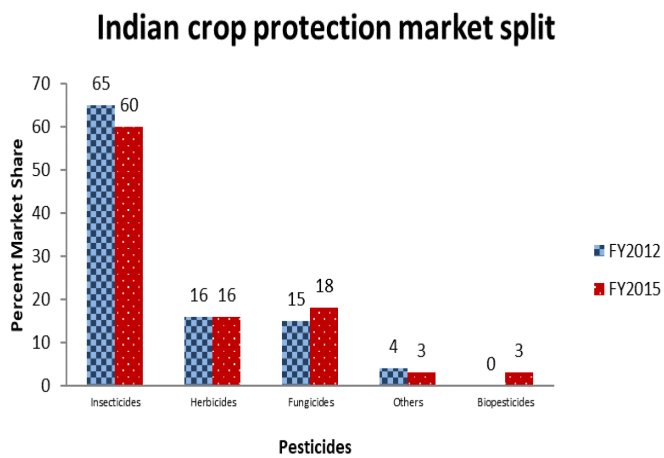

Figure 6: Source: Industry analysis by Tata strategic

Therefore, Bio-pesticides look like the next big thing in the industry and offer advantages of being more environmentally friendly and more effective than the traditional chemicals; as insecticides are mostly used on rice and cotton crops whereas herbicides are majorly used for Rice and wheat crops. Fungicides are used for fruits and vegetables and rice. Farmers are now moving from cash crops to fruits and vegetables. Bio pesticides include all biological materials organisms, which can be used to control pests. Currently a small segment, bio-pesticides market is expected to grow in the future owing to government support and increasing awareness about use of non-toxic, environment friendly pesticides. As bio pesticides are based on pathogenic microbes specific to target pest which proved to be ecologically effective solution to control pest in very small quantity and also it decomposes quickly. Therefore, they pose less threat to the environment and to human health.

In Indian market, there are 115 insecticides, 82 fungicides, 87 herbicides, 23 plant growth regulators and 81 Bio pesticides are registered and approved under the Insecticides Act, 1968 by government of India (Figure 7). Globally, there are 175 registered bio pesticides active-ingredients and 700 products available in the market. The Indian Bio pesticides Market is expected to reach USD XX million by 2022 from USD 70.45 million in 2016 growing with a CAGR of 17.08.

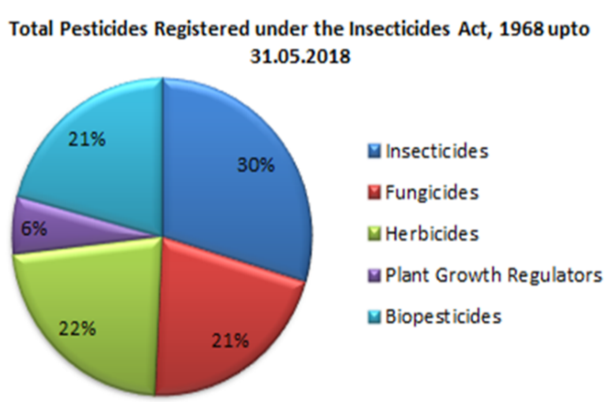

Figure 7: Total number of pesticides available in market under the Insecticides Act, 1968

Recent advances

While the prevalence of chemical or synthetic pesticides, bio pesticide is gaining interest because of its less risk and more environmental safety, target-specificity, efficacy and biodegradability. Globally, the use of Bio pesticides is increasing tremendously by 10% every year and it was covered only 3% of the plant protectants in FY15 but its growth rate is expected to increase by 14.1% during the forecast period (2018-2023). It was also valued at USD 2790.0 million in 2017 according to the Global Bio pesticides Market. Therefore, bio pesticide is one of the promising alternatives to manage animal, human health and environmental concern. Approximately 90% of the bio pesticides are derived from one microbe i.e. entomopathogenic bacterium, *Bacillus thuringiensis*. Currently, there are about 60 bio pesticide products registered in the EU than in the US, India, Brazil, or China which are about to be 200 products in the US market[84, 85].

In fact, many countries have amended their policies to reduce the usage of chemical pesticides and promoting bio pesticides use; however, there are systems that are designed for chemical pesticides regulating the use of bio pesticides and created barriers for bio pesticide industry by imposing the high costs[86]. Major barriers are lack of profile of bio pesticide, relative immaturity of policy network, limited resources and capabilities and lack of trust between regulators and producers.

For effective use of bio pesticides, several technological and policy measures have been identified which is required to reduce the excess use of chemical pesticides. Also, there is a need to spread the awareness among the farmers, government agencies, manufacturers, policy makers and common man for the use of bio pesticides. Some are proved to be excellent alternatives to the chemical pesticides, and some are under the process of development. Various approaches are being applied for the development of effective and efficient bio pesticides like recombinant DNA technology, Novel fusion proteins for next-generation bio pesticides. Some bio pesticides are based on locally available plants like neem, garlic, triphala etc. which are easily processed and available to farmers[87].

CONCLUSION

From the past years, agriculture is facing destruction problems caused by various pests and it has been controlled to a great extent by the use of chemical pesticides. But due to wide and great use of these chemical pesticides, several health and environmental issues have been raised. Therefore, this has raised a need of an ecofriendly alternative. With the facts that due to increase demand of residue free crops, effective in small amounts, decompose quickly and easier registration than chemical pesticides, market of bio pesticide is growing unexpectedly. Now days, bio pesticides are taking attention globally because of its potential and less risk to human and environment. Therefore, cooperation is needed between public and private sectors to increase the production and sale of this environmentally safe alternative. Additionally, more research is needed towards integration of biological agents into production system which maintain low cost product quality and availability. Thus, various aspects of bio pesticides which covers the current status, constraints, prospects and regulatory network towards their effective and efficient use for the benefit of humankind have to be reviewed regularly.

REFERENCES

1. World Population Prospects. The 2017 Revision: Key Findings and Advance Tables. United Nations Department of Economic and Social Affairs, Population Division. Retrieved 2019-01-05; 2017.
2. Reiler E, Jørs E, Bælum J, Huici O, Alvarez Caero MM and Cedergreen N. The influence of tomato processing on residues of organochlorine and organophosphate insecticides and their associated dietary risk. Sci Total Environ 2015; 527–528: 262–269.
3. Lu D, Wang D, Ni R, Lin Y, Feng C and Xu Q. Organochlorine pesticides and their metabolites in human breast milk from Shanghai, China. Environ. Sci. Pollut. Res. Int 2015; 22: 9293–9306.
4. Waliszewski G, SM, Gómez-Arroyo, S, Infanzón, RM, Carvajal O, Villalobos Pietrini R, Trujillo PY and Maxwell Hart M. Persistent organochlorine pesticide levels in bovine fat from México. Food Addit Contam 2004; 21: 774-780.
5. Turusov V, Rakitsky V and Tomatis L. Dichlorodiphenyltrichloroethane (DDT): ubiquity, persistence, and risks. Environ Health Perspect 2002; 110: 125–128.
6. Lemaire G, Terouanne B, Mauvais P, Michel S and Rahman R. Effect of organochlorine pesticides on human androgen receptor activation *in vitro*. Toxicol Appl Pharmacol 2004; 196: 235–246.
7. Eskenazi B, Marks AR, Bradman A, Fenster L, Johnson C and Barr DB. In utero exposure to dichlorodiphenyltrichloroethane (DDT) and dichlorodiphenyldichloroethylene (DDE) and neurodevelopment among young Mexican American children. Pediatrics 2006; 18: 33–241.
8. Tiemann U. *In vivo* and *in vitro* effects of the organochlorine pesticides DDT, TCPM, methoxychlor, and lindane on the female reproductive tract of mammals: a review. Reprod. Toxicol 2008; 25: 316–326.
9. Freire C, Koifman RJ and Koifman S. Hematological and hepatic alterations in brazilian population heavily exposed to organochlorine pesticides. J Toxicol Environ. Health A 2015; 78: 534–548.
10. Gasnier C, Dumont C, Benachour N, Clair E, Chagnon MC and Seralini GE. Glyphosate-based herbicides are toxic and endocrine disruptors in human cell lines. Toxicology 2009; 262: 184–191.
11. Thongprakaisang S, Thiantanawat A, Rangkadilok N, Suriyo T and Satayavivad J. Glyphosate induces human breast cancer cells growth via estrogen receptors. Food Chem. Toxicol 2013; 59: 129–136.
12. Jaga K and Dharmani C. Sources of exposure to and public health implications of organophosphate pesticides. Rev Panam Salud Publica 2003; 14: 171–185.
13. Karami-Mohajeri S and Abdollahi M. Toxic influence of organophosphate, carbamate, and organochlorine pesticides on cellular metabolism of lipids, proteins, and carbohydrates: a systematic review. Hum Exp. Toxicol 2011; 30(9): 1119–1140.
14. Li D, Huang Q, Lu M, Zhang L, Yang Z and Zong M. The organophosphate insecticide chlorpyrifos confers its genotoxic effects by inducing DNA damage and cell apoptosis. Chemosphere 2015; 135: 387–393.
15. Lin JN, Lin CL, Lin MC, Lai CH, Lin HH and Yang CH. Increased risk of dementia in patients with acute organophosphate and carbamate poisoning: a nationwide population-based cohort study. Med (Baltimore) 2015; 94: e1187.
16. Rauh VA, Garcia WE, Whyatt RM, Horton MK, Barr DB and Louis ED. Prenatal exposure to the organophosphate pesticide chlorpyrifos and childhood tremor. Neurotoxicol 2015; 51: 80–86.
17. Swanson NL, Leu A, Abrahamson J and Wallet B. Genetically engineered crops, glyphosate and the deterioration of health in the United States of America. J Org Syst 2014; 9: 6–37.
18. Goad ER, Goad JT, Atieh BH and Gupta RC. Carbofuran-induced endocrine disruption in adult male rats. Toxicol Mech Methods 2004; 14: 233–239.
19. Soloneski S, Kujawski M, Scuto A and Larramendy ML. Carbamates: a study on genotoxic, cytotoxic, and apoptotic effects induced in Chinese hamsterovary (CHO-K1) cells. Toxicol *In vitro* 2015; 29: 834–844.
20. Li Q, Kobayashi M and Kawada T. Carbamate pesticide-induced apoptosis in human T lymphocytes. Intl J Environ Res Public Health 2015; 12: 3633–3645.
21. Zheng T, Zahm SH, Cantor KP, Weisenburger DD, Zhang Y and Blair A. Agricultural exposure to carbamate pesticides and risk of non-hodgkin lymphoma. J Occup Environ Med 2001; 43: 641–659.
22. Denison MS, Phelan D, Winter GM and Ziccardi MH. Carbaryl, a carbamate insecticide, is a ligand for the hepatic ah (dioxin) receptor. Toxicol Appl Pharmacol 1998; 152: 406–414.
23. Wesseling C, Keifer M, Ahlbom A, McConnell R, Moon JD and Rosenstock L. Long-term neurobehavioral effects of mild poisonings with organophosphate and n-methyl carbamate pesticides among banana workers. Intl J Occup Environ Health 2002; 8: 27–34.
24. Jaensson A, Scott AP, Moore A, Kylin H, HakanOlsen K. Effects of a pyrethroid pesticide on endocrine responses to female odours and reproductive behaviour in male parr of brown trout (*Salmo trutta* L.). Aquat Toxicol 2007; 81: 1–9.
25. Jurewicz J, Radwan M, Wielgomas B, Sobala W, Piskunowicz M and Radwan P. The effect of environmental exposure to pyrethroids and DNA damage in human sperm. Syst Biol Reprod Med 2015; 61: 37–43.

26. Syed F, John PJ and Soni I. Neurodevelopment consequences of gestational and lactational exposure to pyrethroids in rats. Environ Toxicol 2015; 31(12): 1761-1770.
27. Caron-Beaudoin E, Denison MS and Sanderson JT. Effects of neonicotinoids on promoter-specific expression and activity of aromatase (CYP19) in human adrenocortical carcinoma (H295R) and primary umbilical vein endothelial (HUVEC) cells. Toxicol. Sci 2016; 149(1): 134–144.
28. Breckenridge CB, Sawhney Coder P, Tisdel MO, Simpkins JW, Yi KD and Foradori CD. Effect of age, duration of exposure, and dose of atrazine on sexual maturation and the luteinizing hormone surge in the female Sprague-Dawley rat. Birth Defects Res B Dev. Reprod Toxicol 2015; 104: 204–217.
29. Jin Y, Wang L, Chen G, Lin X, Miao W and Fu Z. Exposure of mice to atrazine and its metabolite diaminochlorotriazine elicits oxidative stress and endocrine disruption. Environ Toxicol Pharmacol 2014; 37: 782–790.
30. Kettles MK, Browning SR, Prince TS and Horstman SW. Triazine herbicide exposure and breast cancer incidence: an ecologic study of Kentucky counties. Environ Health Perspect 1997; 105: 1222–1237.
31. Kavitha S, Sonal S, Ananth P, Ananthakrishna SB, Rajesh V and Jagadeswara R. Early Paraquat - A deadly poison: Report of a case and review. Indian J Crit Care Med 2013; 17(3): 182–184. http://dxdoi 10.4103/0972-5229.117074.
32. Arts J, Schuit G, Schipper A and Kleij van der BA. Case report of paraquat poisoning. Eur J .Hosp Pharm 2006; 12: 22–24.
33. Holland NT. Micronucleus frequency and proliferation in human lymphocytes after exposure to herbicide 2, 4-dichlorophenoxyacetic acid *in vitro* and *in vivo*. Mutat Res 2002; 521(1-2): 165-178.
34. Bortolozzi AA, Evangelista DeDuffard AM, Duffard RO and Antonelli MC. Effects of 2,4 dichlorophenoxyacetic acid exposure on dopamine D2-like receptors in rat brain. Neurotoxicol Teratol 2004; 26(4): 599-605.
35. World Health Organization Geneva, A.F. Pelfrène, Charbonnières-lesBains, DINITRO-ortho-CRESOL Environmental Health Criteria; 2000. p. 220.
36. Funakoshi, T, Ueda K, Kado K and Kojima S. Mechanism of mobilization of cadmium by dithiocarbamates in rat primary hepatocyte cultures. Res Commun Mol Pathol Pharmacol 1996; 93: 177–186.
37. U.S. Environment (Protection). Act.Integrated Risk Information System (IRIS) on 1, 2-Dibromoethane. National Center for Environmental Assessment, Office of Research and Development, Washington, DC; 1986.
38. Toxnet. National library of medicine's toxicology data network. Hazardous Substances Data Bank (HSDB). Public Health Service. National Institute of Health, US Department of Health and Human Services. NLM, Bethesda; 1975-1986.
39. Paris MA and Gottlieb D. Mechanism of Action of the Fungicide Thiabendazole, 2-(4′-Thiazolyl) Benzimidazole. Appl Microbiol 1970; 20(6): 919–926.
40. Lv X, Pan L, Wang J, Lu L, Yan W, Zhu Y, Xu Y, Guo M and Zhuang S. Effects of triazole fungicides on androgenic disruption and CYP3A4 enzyme activity. Environ Pollut 2017; 222: 504-512.
41. Machera K. Developmental toxicity of cyproconazole, an inhibitor of fungal ergosterol biosynthesis, in the rat. Bull. Environ Contam Toxicol 1994; 54: 363–369.
42. Walker A and Welch SJ. Enhanced Biodegradation of Dicarboximide Fungicides in Soil Enhanced Biodegradation of Pesticides in the Environment Wellesbourne, Warwick, United Kingdom ACS Symposium Series 1990; 426: 53–67.
43. Anfossi L, Sales P and Vanni A. Degradation of anilinopyrimidine fungicides photoinduced by iron (III)-polycarboxylate complexes. Pest Mang Sci 2006; 62(9): 872-879.
44. Lohmus M, Ingmar J, Frank van de G and Bart JR. Rodents as Potential Couriers for Bio terrorism Agents Bio security and Bio terrorism: Bio defense Strategy, Practice, and Sci 2013; 11(1): 247-257.
45. Yang RS, Witt KL, Alden CJ and Cockerham LG. Toxicology of methyl bromide. Rev Environ Contam Toxicol 1995; 142: 65-85.
46. U.S. Environmental Protection Agency. Integrated Risk Information System (IRIS) on 1, 2-Dibromoethane. National Center for Environmental Assessment, Office of Research and Development, Washington, DC; 1999.
47. Sudakin DL and Trevathan WR. DEET: a review and update of safety and risk in the general population. J Toxicol Clin Toxicol 2003; 41: 831–839.
48. Kabaluk, JT, Svircev AM, Goettel, MS and Woo SG. The use and regulation of microbial pesticides in representative jurisdictions worldwide. IOBC Global; 2010. p. 99.
49. Roh JY, Choi JY, Li MS, Jin BR and Je YH. *Bacillus thuringiensis* as a specific, safe, and effective tool for insect pest control. J of Microbiol and Biotechnol 2007; 17: 547-559.
50. Khachatourians GG. Insecticides microbials. Appl Microbiol: Agro/Food; 2009. p. 95-109.
51. Witzgall PL, Stelinski L and Thomson D. Codling moth management and chemical ecology. Annu Rev Entomol 2008; 53: 503–522.
52. Weichenthal S, Moase C and Chan P. A Review of pesticide exposure and cancer incidence in the agricultural health study cohort. Environ Health Perspect 2010; 118: 1117-1125.
53. Oldfield M. The Value of Conserving Genetic Resoucres.U.S. Department of the Interior, National Pardk Service, Washington, D.C; 1984. p. 360.
54. Isman MB. The role of botanical insecticides, deterrents and repellents in modern agriculture and an increasingly regulated world. Annu Rev Entomol 2006; 51: 45–66.
55. Mordue AJ and Blackwell A. Azadirachtin: an update. J Insect Phys 1993; 39: 903–924.
56. Barton DHR, Jeger O, Prelog V and Woodward RB. The constitutions of cevine and some related alkaloids. Experientia 1854; 10: 81–90.
57. Schmelz I. Nicotine and other tobacco alkaloids. In Naturally Occurring Insecticides; Jacobson, M.; Crosby, D.G, Editor Marcel Dekker: New York, NY, USA; 1971. p. 99–136.
58. Glenn FK and Margaret H. Spider Venom Peptides: Structer, Pharmacology and Potential for Control of Insect pests. Ann Rev of Entomol 2013; 58: 475-496.
59. De Morais CL, Reis BDL, Hamacek FR and Santana HMP. Chemical characteristics and bioactive compounds of cooked pequi fruits (*Caryocarbrasiliense* Camb.) from the Brazilian Savannah. Fruits 2013; 68: 3–14.
60. Ansante TF, Ribeiro, LP and Vendramim JD. Acute and chronic toxicities of an Annonin-based commercial bioinsecticide and a joint mixture with a Limonoid-based formulation to the fall armyworm. Neotropical Entomol 2017; 46(2): 216–222.
61. Khan I and Qamar A. Comparative bioefficacy of selected plant extracts and some commercial biopesticides against important

household pest, *Periplaneta Americana*. J of Entomol and Zool Studies 2015; 3(2): 219-224.
62. Crocker RL. Laboratory testing of milky spore disease, *Bacillus popilliae*, for control of *Phyllophaga crinita* white grubs. Progress Report Texas Agricultural Experiment Station 1992; 4891–4921: 89–91.
63. Arena JP, Liu KK, Paress PS, Frazier EG, Cully DF, Mrozik H and Schaeffer J. The mechanism of action of avermectins in *Caenorhabditis elegans*: Correlation between activation of glutamate-sensitive chloride current, membrane binding, and biological activity. J Parasitol 1995; 81: 286–294.
64. Kornis GI. Avermectins and milbemycins. In Agrochemicals from Natural Products; Godfrey, C.R.A., Editor Marcel Dekker: New York, NY, USA; 1995. p. 215–255.
65. Sparks TC, Crouse GD and Durst G. Natural products as insecticides: the biology, biochemistry and quantitative structure–activity relationships of spinosyns and spinosoids. Pest Mang Sci 2001; 57: 896–905.
66. Snyder DE, Meyer J, Zimmermann AG, Qiao M, Gissendanner SJ, Cruthers LR, Slone RL and Young DR. Preliminary studies on the effectiveness of the novel pulicidespinosad, for the treatment and control of fleas on dogs. Vet. Parasitol 2007; 150: 345–351.
67. Lydon J and Duke SO. Inhibitors of glutamine biosynthesis. In Plant Amino Acids: Biochemistry and Biotechnology; Singh, B.K., Editor Marcel Dekker: New York, NY, USA; 1999. p. 445–464.
68. Abbas HK, Tanaka T, Duke SO, Porter JK, Wray EM, Hodges L, Sessions AE, Wang E, Merrill AH and Riley RT. Fumonisin- and AAL-toxin-induced disruption of sphingolipid metabolism with accumulation of free sphingoid bases. Plant Physiol 1994; 106: 1085-1093.
69. Revathi K, Chandrasekaran R, Thanigaivel A, Kirubakaran SA, Sathish-Narayanan S and Senthil-Nathan S. Effects of *Bacillus subtilis* metabolites on larval *Aedesa egypti* L. Pestic Biochem. Physiol 2013; 107: 369–376.
70. Carlton BC. Genetics of Bt insecticidal crystal proteins and strategies for the construction of improved strains. In: Duke SO, Menn JJ, Plimmer JR (eds), Pest control with enhanced environmental safety. ACS symposium series 524, American Chemical Society, Washington, DC; 1993. p. 326–337.
71. Copping LG and Menn JJ. Biopesticides: a review of their action, applications and efficacy. Pest Mang Sci 2000; 56: 651–676.
72. Mnyone LL, Koenraadt CJM, Lyimo IN, Mpingwa MW, Takken W and Russel, TL. Anopheline and culicine mosquitoes are not repelled by surfaces treated with the entomopathogenic fungi *Metarhiziumanisopliae* and *Beauveriabassiana*. Parasite Vectors 2010; 3: 80-87.
73. Lakshmi LG, Uthamasamy S and Murali Baskaran RK. Comparative biology and predatory potential of Australian ladybird beetle (*Cryptolaemus montrouzieri*) on *Planococcus citri* and *Dactylopius tomentosus*. Indian J Agr Sci 1999; 69(8): 605-606.
74. Naik VCB, Subbanna A, Suneetha, P and Krishna, MSR. Impact of transgenic events on *Helicoverpa armigera* (Hubner) and *Spodoptera litura* (Fabricius) on cotton in India. Res J of Biotechnol 2015; 10(6): 91-99.
75. TapwalA, Kumar R, Gautam N and Pandey S. Compatibility of *Trichoderma viride* for selected fungicides and botanicals. Intl J of Plant Pathol 2012; 3(2): 89-94.
76. US Environmental Protection Agency Office of Pesticide Programs. RED Fact Sheet: Methyldithiocarbamate Salts - Metam Sodium/Potassium and MITC; 2008.
77. Isman MB. Repellents in modern agriculture and an increasingly regulated world. Annual Review of Entomology 2005; 51: 45-66.
78. Higbee EC. *Lonchocarpus*: A fish-poison insecticide. Economic Bot. 1947; 1(4): 118–119.
79. Dayan FE, Duke SO, Sauldubois A, Singh N, McCurdy C and Cantrell C. p-Hydroxyphenylpyruvate dioxygenase is a herbicidal target site for beta-triketones from *Leptospermum scoparium*. Phytochem 2007; 68: 2004–2014.
80. Sauter H, Ammermann F, Roehl F. Strobilurins- from natural products to a new class of fungicides. In Crop protection agents from nature. (Ed. LG Copping); 1996. p. 50-81. (The Royal Society of Chemistry, Thomas Graham House: Cambridge, UK.)
81. Bang KH, Lee DW, Park HM and Rhee YH. Inhibition of fungal cell wall synthesizing enzymes by trans-cinnamaldehyde. Biosci Biotechnol Biochem 2000; 64(5): 1061-3.
82. Van Emden HF. Service MW. Pest and vector control. Cambridge, UK: Cambridge University Press; 2004.
83. Indian Agrochemical Industry. Report on Next Generation Indian Agriculture - Role of Crop Protection Solutions. FICCI; 2016.
84. Czaja K, Goralczyk K, Strucinski P, Hernik A, Korcz W, Minorczyk M, Łyczewska M and Ludwicki JK. Bio pesticides—towards increased consumer safety in the European Union. Pest Manag Sci 2015; 71: 3–6.
85. Balog A, Hartel T, Loxdale HD and Wilson K. Differences in the progress of the bio pesticide revolution between the EU and other major crop-growing regions. Pest Manag Sci 2017; 73: 2203–2208.
86. Kumar S, Singh A. Bio pesticides: Present status and the future prospects. J Fertil Pestic 2015; 6: 129.
87. Marrone PG. The market and potential for bio pesticides. In Bio pesticides: State of the Art and Future Opportunities; Gross, A.D., Coats, J.R., Duke, S.O., Seiber, J.N., Eds.; American Chemical Society: Washington, DC, USA; 2014. p. 245–258.

Cite this article as:

Sarika Chaturvedi and Shikha Khandelwal. A Review on comparative analytical approach towards Chemical pesticides to Bio pesticides. Int. Res. J. Pharm. 2019;10(9):1-12 http://dx.doi.org/10.7897/2230-8407.1009254

Source of support: Nil, Conflict of interest: None Declared