Information on Activities Regarding Biochemical Pesticides: An Ecological Friendly Plant Protection against Insects

Muhammad Sarwar

***Abstract*— Although there is still much work to be done in the field of pest control, however, the insect pests management technologies and information have reached well beyond our thoughts. There are some interesting developments in pesticides technology resulting in the flush of greener products and among these are existences of biochemical pesticides. The goal of this paper is to emphasis on the use of reduced-risk chemicals for insect pests controlling needs as alternatives to riskier conventional pesticides. The reduced risk designation can be applied only to certain uses of a particular chemical such as biochemical pesticides that are naturally occurring and control pests through non-toxic routes. Examples of biochemical pesticides categories are semiochemicals (chemical signals) including pheromones (acting between individuals within a species) and allelochemicals (acting between individuals of different species), hormones, plant extracts, enzymes, feeding deterrents, repellents, confusants, plant growth regulators and insect growth regulators. Pesticides to be included in these categories must be naturally occurring, or if man synthesizes such chemicals, and then these must be structurally identical to naturally occurring chemicals. Because biochemical pesticides are naturally occurring they pose much less health and environmental concerns than conventional pesticides. Methods for crop protection based on semiochemicals show advantages over methods based on conventional insecticides. Applications of semiochemicals for insect pest management however, have been limited. Some recent studies carried out in an interdisciplinary research program are presenting that in spite of the chemodiversity in nature, it is striking that many simple and common compounds are important as chemical signals. Biochemical pesticides have been expediting the review of conventional pesticides that meet certain criteria such as low toxicity to humans and nontarget organisms including fish and birds, low risk of ground water contamination or runoff, low potential for pesticide resistance, and demonstrate efficacy and compatibility with integrated pest management (IPM).**

***Index Terms*− Pesticide, Biochemical, Semiochemical, Enzyme, Hormone, Pheromone**

I. INTRODUCTION

Owing to the importance as public health, various insecticides have been used directly or indirectly in the control of insect pests on crops, orchards and vegetables. All the way through the world, insects have developed resistance to these insecticides and the use of pesticides in food production inevitably leaves residues in the final products.

Furthermore, resistance has been recorded for most conventional insecticides. As a significance, there is need to arrange for motivation to study new alternatives and more ecologically and adequate approaches of insect control. Since the identification of biological pesticides, the biochemical pesticides have received much attention from scientists in biology, chemistry, agriculture and forestry. Many of the findings have come into practical use for monitoring or suppression of insect pests using biochemical pesticides [1], [2].

Biochemical pesticides or biological pesticides are unconventional pesticides derived from such natural materials as animals, plants, bacteria and certain minerals. These include microbial pesticides containing bacteria, fungi, virus, etc., as the active ingredient; plant incorporated protectants i.e., pesticidal substances, which plants produce from added genetic material (such as corn genetically modified to produce *Bacillus thuringiensis* toxins); and biochemical pesticides comprised of naturally occurring substances that control pests by nontoxic mechanisms (such as pheromones or some insect growth regulators). These are naturally occurring substances such as plant extracts, fatty acids or pheromones that control pests by non-toxic mechanisms. Conventional pesticides, by contrast, are synthetic materials that usually kill or inactivate the pests. Biochemical pesticides include substances that interfere with growth or mating, such as plant growth regulators, or substances that repel or attract pests, such as pheromones. It is sometimes difficult to determine whether a natural pesticide controls the pest by a non-toxic mode of action to determine whether a pesticide meets the criteria for a biochemical pesticide. The olfactory system of insects is very sensitive, and limited amounts of semiochemicals are needed for control. This is demonstrated by the current application of pheromones for control (mating disruption by confusion strategy) of codling moth (Cydiapomonella) in apple orchards. A dispenser for insect control emits about 1 µg/ ha, and the amounts of pheromone needed for control using confusion strategy are only about 1 g/ ha. On the other hand, the amount of insecticide needed for a conventional treatment in this case is about 1 kg/ ha. Furthermore, the use of nonselective insecticides is questioned because of ecological and environmental reasons.nOriental Beetle MD is a pheromone product used for controlling oriental beetle, which is a grub pest of container-grown plants (and also turf) in some regions. It is one of the few materials available to growers of ornamentals for controlling insects via mating disruption [3], [4].

II. BIOCHEMICAL PEST CONTROL AGENTS

There are several general biologically functional classes of reduced-risk biochemical pesticides labeled for crops and ornamentals as well as vegetables. Important biochemical pest control agents are briefly described below:-

Muhammad Sarwar, Nuclear Institute for Agriculture & Biology (NIAB), Faisalabad-38950, Punjab, Pakistan

A. Semiochemicals

These are chemicals emitted by plants or animals that modify the behaviour of receptor organisms of like or different kinds. The terms commonly used for various semiochemicals (chemical signals) include pheromones (acting between individuals within a species) and allelochemicals (acting between individuals of different species). Allelochemicals can be categorized into allomones (advantage for sender), kairomones (advantage for receiver), synomones (advantage for both) and apneumones (from non-living sources). Pheromones are substances emitted by a member of one species that modify the behaviour of others within the same species. Allomones are chemicals emitted by one species that modify the behaviour of a different species to the benefit of the emitting species. Kairomones are chemicals emitted by one species that modify the behaviour of a different species to the benefit of the receptor species. Semiochemicals determine insect life situations such as feeding, mating and egg-laying (ovipositing). Semiochemicals are thus potential agents for selective control of pest insects (for definitions of terms used for various chemical signals). Biological control with pheromones or kairomones can be used for detection and monitoring of insect populations. Monitoring is important for the efficient use of conventional or unconventional insecticides. Mating disruption by use of pheromones is a promising and in many cases, it is a successful strategy for pest control (confusion strategy). The use of semiochemicals as feeding deterrents is another strategy. The most common strategy for control by the use of semiochemicals is to attract, trap and kill the pest insects [5].

B. Hormones

These are biochemical agents synthesized in one part of an organism and translocated to another where they have controlling, behavioral, or regulating effects. New approaches to the development of insect control agents have been revealed through the description of natural and synthetic compounds capable of interfering with the processes of development and reproduction of the target insects. The information on novel insecticides that mimic the action of two insect growth and developmental hormone classes is the ecdysteroids and the juvenile hormones. Neuropeptide structures, their biogenesis, action and metabolism also offer the opportunity to exploit novel control agents [6].

C. Plant Extracts

Plants are infact, natural laboratories in which a great number of chemicals are biosynthesized. Many plants have developed natural and biochemical mechanisms to defend themselves from weed competition and animal, insect and fungal attacks. Some of these chemicals discourage feeding by insects and other herbivores. Others provide protection or even immunity from diseases caused by some pathogens. Still others help the plants to compete for resources by discouraging competition among different plant species. By studying the diverse chemistries of many different plant species, scientists have discovered many useful compounds that can be used as biopesticides. Plant extracts have long been used to control insects, wherein dating far back children have been deloused using a powder obtained from the dried flowers of the pyrethrum plant (*Tanacetum cinerariifolium*). The first botanical insecticide dates back, when it has been shown that nicotine from tobacco leaves killed plum beetles. Today, there are a number of biopesticide plant extracts being marketed as insecticides and these products fall into several different classes [7].

Some of the plant products registered as biopesticides include Limonene and Linalool that act on target pests fleas, aphids and mites, also kill fire ants, several types of flies, paper wasps and house crickets. Neem has pesticidal properties against a variety of sucking and chewing insect; while pyrethrum is effective against ants, aphids, roaches, fleas, flies and ticks. Rotenone exhibits insecticidal activity against leaf-feeding insects, such as aphids, certain beetles (asparagus beetle, bean leaf beetle, potato beetle, cucumber beetle, flea beetle, strawberry leaf beetle and others) and caterpillars, as well as fleas and lice on animals. Ryania is found most effective in reducing the larval population of caterpillars such as corn borer, corn earworm, and thrips and others, while Sabadilla has a significant effect against squash bugs, harlequin bugs, thrips, caterpillars, leaf hoppers and stink bug [8].

D. Enzymes

The enzymes are protein molecules, which are the instruments for expression for gene action and that catalyze biochemical reactions. Plant defenses against insect herbivores are mediated, in part, by enzymes that impair digestive processes in the insect gut. Little is known about the evolutionary origins of these enzymes, their distribution in the plant kingdom, or the mechanisms by which they act in the protease-rich environment of the animal digestive tract [9].The transgenic expression of insecticidal proteins such as α-amylase and protease inhibitors is also being evaluated as a potential protective strategy against insects [10].

E. Feeding Deterrents

Feeding deterrent is a compound that once ingested by the insect pest, causes it to stop feeding and eventually to starve to death. Crop damage is inhibited and the insect eventually starves to death. The screening for insecticidal principles from several Chinese medicinal herbs showed that the root bark of *Dictamnus dasycarpus* possessed significant feeding deterrence against two stored-product insects (*Tribolium castaneum* and *Sitophilus zeamais*). From the methanol extract, two feeding deterrents have been isolated by bioassay-guided fractionation. The compounds have been identified as fraxinellone and dictamnine from their spectroscopic data. Fraxinellone and dictamnine have demonstrated to possess feeding deterrent activity against adults and larvae of *T. castaneum* as well as *S. zeamais* [11], [12].

F. Repellents

An insect repellent (also commonly called bug spray) is a substance applied to skin, clothing, or other surfaces which discourages insects (and arthropods in general) from landing or climbing on that surface. Typically compounds which release odors that are unappealing or irritating to insects, include garlic or pepper based insecticides. Insect repellents help to prevent and control the outbreak of insect-borne diseases such as malaria, dengue fever and bubonic plague. Pest creatures commonly serving as vectors for disease include the insects flea, fly, mosquito and the arachnid tick. Repellents researched, which have been shown to provide significantly better protection are *N*,*N*-diethyl-*m*-toluamide, essential oil of the lemon eucalyptus (*Corymbia citriodora*), Icaridin, Nepetalactone, Dimethyl carbate, Dimethyl phthalate, Citronella oil, Neem oil and Metofluthrin, which are promising group of repellents. Sometimes, the synthetic repellents tend to be more effective and longer lasting than natural repellents] 13], [14].

Repellants, confusants, and irritants are not usually toxic to insects, but interfere with their normal behavior and thereby keep the insects from causing damage. Mothballs and mosquito repellants are familiar examples. Wide scale use of synthetic sex pheromones may confuse insects sufficiently that they are unable to mate and produce offspring; a few such products are commercially available, such as for codling moth control in apples. Using insect pheromones in this manner is called mating disruption, a practice that works best in large commercial plantings where it is less likely that mated females will move into the planting from outside of the treated area. Many of these types of behavioral chemicals break down or wash away quickly, and must be reapplied frequently, used in an enclosed area, or formulated to release slowly over a long period [15].

G. Confusants

Confusants are compounds that imitate food sources and are used as traps or decoys to draw damaging insects away from crops. Confusants can also be formulated as concentrated sprays designed to overwhelm insects with so many sources of stimuli that they cannot locate the crop. Not only are plant extracts used directly as insecticides, but they are used also as a source for synthetic insecticides based on analogues developed in the laboratory. Scientists have modified molecules found in plants to be more toxic or more persistent. Common examples of this can be found in the pyrethroid and neonicitinoid families of insecticides, derived from molecules isolated from plants like pyrethrum (*T. cinerariifolium*) and tobacco. The damage caused by the whiteflies *Dialeuropora decempuncta* (Quaintance & Baker), *Aleurodicus disperses* Russell, and *Aleuroclava* sp., to mulberry plants is extensive and they cause a huge economic loss to mulberry leaves which affects silkworm rearing. Previous investigations indicate that neem-based insecticides may be a suitable alternative for pest management in sericulture. Use of neem products in sericultural pest control has many merits. It will also help in the successful introduction of biological controls in plants. Several exotic parasitoids have been found to be highly effective, including two aphelinid parasitoids *Encarsia haitiensis* Dozier and *E. meritoria* Gahan. These are most promising and are reported to minimize the fly pest populations. The parasitization potential and behaviour of the parasitoids have to be carefully assessed before they are introduced to control fly pest populations. There is a need for careful assessment of all these advanced biological technologies in order to develop a profitable, safe and durable approach for whitefly control in sericulture [16].

H. Plant Growth Regulators

Simply, plant growth regulators also known as growth regulators or plant hormones are chemicals used to alter the growth of a plant or plant part. From the regulatory control perspective, plant growth regulators are classified under pesticides. Natural plant regulators are chemicals produced by plants that have toxic, inhibitory, stimulatory, or other modifying effects on the same or other species of plants. Some of these are termed plant hormones or phytohormones. Some plant oils can act as effective contact herbicides through a variety of mechanisms such as disrupting cell membranes in plant tissue, inhibiting amino acid synthesis, or precluding production of enzymes necessary for photosynthesis. Examples of minimum risk pesticides include products containing active ingredients of cottonseed, clove and garlic oils, cedar oil, and rosemary and peppermint oil [17].

I. Insect Growth Regulators

The insect growth regulators (IGRs) have been used in a variety of practical applications and are described as agents that elicit their primary action on insect metabolism, ultimately interfering and disrupting the process of growth, development and metamorphosis of the target insects, particularly when applied during the sensitive period of insect development. Biochemical insect growth regulators have a unique mode of action separate from most chemical insecticides. Generally speaking, these products prevent insects from reaching a reproductive stage, thereby reducing the expansion of pest populations. The direct impact of IGRs on target pests combined with the preservation of beneficial insects and pollinators aids to growers in maximizing yield and product quality. The IGRs can be divided into two broad categories; i.e., those that disrupt the hormonal regulation of insect metamorphosis, and those that disrupt the synthesis of chitin, a principal component of insect exoskeletons. Agricultural applications currently focus on the first category of compounds, and these products are also known as 'hormone mimics'. Azadirachtin is one of the most widely used botanical insect growth regulators. Because of its structural resemblance to the natural insect molting hormone ecdysone, azadirachtin interrupts molting, metamorphosis and development of the female reproductive system. Immature insects exposed to azadirachtin (mainly by ingestion) may molt prematurely or die before they can complete a properly timed molt. Those insects that survive a treatment are likely to develop into deformed adults incapable of feeding, dispersing, or reproducing. Since beneficial insects, predators and pollinators do not feed directly on the treated foliage, biochemical insect growth regulators are considered 'soft' on beneficial insects such as honeybees, lady bugs, green lacewings and the parasitic wasps. Due to their unique mode of action, biochemical insect growth regulators have played an important role in integrated pest management systems and as an effective resistance management tool. A good example is the use of azadirachtin IGR in aphid population management programs for lettuce crop protection. Integrated use of azadirachtin provides control by impacting the larvae and nymphs of multiple aphid species, breaking the life cycle before they become reproducing adults. Another azadirachtin success story is its use for pear psylla control on pears, where growers integrate traditional control products, azadirachtin and kaolin clay for an effective pest management with significantly reduced use of harmful chemical insecticides [18].

The research work has been carried out to evaluate the biochemical effects of five insect growth regulators; applaud (buprofezin), consult (hexaflumuron) and match (lufenuron) as chitin synthesis inhibitors; mimic (tebufenozide) as ecdysone agonist and admiral (pyriproxyfen) as juvenile hormone analogue against the housefly *M. domestica*. The IGRs have been applied by feeding 1st instar larvae on diets mixed with these IGRs at 100 and1000 ppm for three days to determine the effects of these IGRs on the glucose, protein and the amino acid content as well as the phosphatase and transaminase enzymes. The obtained results indicate that all the tested IGRs except applaud increased the glucose content in the homogenate of 3rd larval instar of *M. domestica*. The total protein content and total concentration of amino acids increased with applaud, admiral and mimic, while decreased with match and consult. In addition, the tested IGRs significantly increased the activity of acid and alkaline phosphatase .Mimic exhibited a severe reduction in the activity of AcP. Admiral, mimic and applaud induced a significant stimulatory effect on total AST activity, while match induced inhibitory effect at 1000 ppm. Consult has no effect on the total activity of AST. With respect to the total ALT activity, applaud and admiral induced a significant stimulatory effect, in contrast, match and consult elicited inhibitory effect on the total ALT activity [19].

Lectins are hemagglutinating proteins that promote cellular responses due to their interaction with glycosylated molecules. Trypsin inhibitors have been described as endogenous regulators of proteolytic enzymes and as storage proteins. Plant lectins and trypsin inhibitors with insecticidal activity may become an alternative to synthetic insecticides that adversely affect the environment and have promoted the emergence of resistant organisms. These proteins exert deleterious effects on larval survival, weight, feeding ability, and development of insects as well as morphology of larvae, pupae and adults. The digestive processes in larval gut are highly active and their integrity is an essential aspect in insect development. Plant lectins and trypsin inhibitors can modulate the activity of digestive enzymes in larval gut. This research reports larvicidal lectins and trypsin inhibitors isolated from different plant tissues (e.g., bark, heartwood, leaves, flowers and seeds) with potential applications in the control of numerous insect species, including *Achaea janata, Aedes aegypti, Anthonomus grandis, Callosobruchus maculatus, Corcyra cephalonica, Ephestia kuehniella, Helicoverpa armigera, Lacanobia oleracea, Ostrinia nubilalis, Spodoptera littoralis, Spodoptera litura* and *Zabrotessub fasciatus*. The changes in morphology of larvae treated with lectins or trypsin inhibitors, as well as the effect of these proteins on larval â-amylase, â-glucosidase, protease and aminopeptidase activities, are noted [20].

III. Benefits of Biochemical Pesticides

Crops treated with some biochemical pesticides produce and accumulate elevated levels of specialized proteins and other compounds which inhibit the development of fungal and bacterial diseases. In effect, the crop's immune system is triggered to defend against destructive diseases. Using plant extracts as biopesticides offers growers many unique benefits. Generally, plant-based compounds degrade rapidly, reducing the risk of residues on food. Many of these products have very short preharvest intervals. Most products show wide windows of crop safety and resistance to these compounds is not developed as quickly as with synthetic pesticides due to multiple modes of action. Many plant extracts used as insecticides are fast-acting, quickly inhibiting insect feeding and additional crop damage. And, because they act on the insect's gut and rapidly decompose in the environment, many plant extract insecticides are more selective to insect targets and safer to beneficial insects [21], [22].

IV. Integrated Pest Management (IPM)

Integrated Pest Management (IPM) though is an easy solution to eliminate insect's damage, yet it is not a magic bullet that may solve all our problems in one shot. Unfortunately, pest management is complicated and there is not a simple solution to pest problems. It is based on the fact that combined strategies for pest management are more effective in the long run than a single strategy. It is the blending of all effective, economical and environmentally sound pest control methods into a single but flexible approach to managing pests. Integrated pest management is a dynamic and evolving practice wherein specific management strategies can vary from crop to crop, location to location, and year to year, based upon changes in pest populations and their natural controls. The growers who practice IPM realize that it is neither possible nor economically feasible to eliminate all pests, but instead pest populations should be managed below economically damaging levels. Growers using of the IPM approach recognize and understand the importance of the controls provided by nature. When human intervention is necessary, the least invasive practices, such as plant resistance, biological control, and cultural control, should be used because these are the practices that fit best into sustainable agriculture. Highly disruptive or environmentally damaging practices should be used only as a last resort. Chemical pesticides should be used only when necessary, based upon frequent and routine monitoring of pest populations. Natural enemy populations should also be monitored so that their impact on pests can be determined. When pesticides are necessary, if possible, only those products should be used that are not detrimental to natural enemies. As specific new approaches are developing, these too can be incorporated into the program as appropriate. Modern pest managing can be most effective if these are knowledgeable about the pests, beneficial insects and all of the control options available [23], [24], [25], [26].

V. Conclusion

This publication addresses the information on activities regarding biochemical pesticides which are an ecological friendly protection against insects. Chemical control is the quick solution to minimize the insect pests population, however, the indiscriminate and large-scale use of highly poisonous synthetic chemical pesticides has resulted in ecological imbalance, in addition to their toxic effects on living organisms including human beings. Hence, there is a need for developing methods and materials within an eco-friendly atmosphere. A number of promising possibilities can be anticipated for pest control including through biochemical pesticides all of which need to be explored and prudently tapped for their implementation in integrated pest management programs. Products used for crop safety and public health must show evidence that these are effective against the target pests. Products intended for use on food plants have additional requirements such as requires minimum-risks and labels to display pesticide use directions along with percent concentrations of all ingredients. In conclusion, biochemical pesticides are a group of chemicals for controlling and enhancing the natural plant protection processes to better meet the requirements of food supply in general. As a well-accepted principle, all pesticides, including biochemicals, have to be registered with the competent authority before application in agriculture. Their safety and efficacy will be thoroughly assessed during the registration process, and proper use of these registered pesticides will result in minimal residue in food and insignificant food safety risk. Current research on biochemicals and their applications for control of pest insects has shown that even rather common and structurally simple compounds can act as important chemical signals and exhibit biological activity on many different species and one single compound can have different functions on different species. Methyl salicylate is a good representative of this type of semiochemical. Furthermore, it is clear that multidisciplinary research work in the area of ecological chemistry is successful and will provide tools for sustainable methods for control of many pest insects and other pest organisms. The use of trade names in this publication is solely for the purpose of providing specific information and does not guarantee or warranty the products named, and references to them in this publication does not signify the approval to the exclusion of other products of suitable composition.

REFERENCES

[1] M. Sarwar, "The Dangers of Pesticides Associated with Public Health and Preventing of the Risks". International Journal of Bioinformatics and Biomedical Engineering, 2015, 1 (2): 130-136.

[2] M. Sarwar, "Commonly Available Commercial Insecticide Formulations and Their Applications in the Field". International Journal of Materials Chemistry and Physics, 2015, 1 (2): 116-123.

[3] P. Witzgall, A.C. Backman, M. Svensson, U.T. Koch, F. Rama, A. El-Sayed, J. Brauchli, H. Arn, M. Bengtsson, and J. Lofqvist, "Behavioral observations of codling moth, *Cydia pomonella*, in orchards permeated with synthetic pheromone". BioControl, 1999, 44: 211-327.

[4] T.G.T. Jaenson, S. Garboui, and K. Palsson, "Repellency of Oils of Lemon Eucalyptus, Geranium, and Lavender and the Mosquito Repellent MyggA® Natural to *Ixodes ricinus* (Acari: Ixodidae) in the Laboratory and Field". Journal of Medical Entomology, 2006, 43 (4): 731-736.

[5] T. Norin, "Semiochemicals for insect pest management". Pure Appl. Chem., 2007, 79 (12): 2129-2136.

[6] K.H. Hoffmann, and M.W. Lorenz, "Recent advances in hormones in insect pest control". Phytoparasitica, 1998, 26 4): 323-330.

[7] M.S. Fradin, and J.F. Day, "Comparative Efficacy of Insect Repellents against Mosquito Bites". J. Med., 2002, 347 (1): 13-18.

[8] S. Mazid, C.K. Jogen, and C.R. Ratul, "A review on the use of biopesticides in insect pest management". International Journal of Science and Advanced Technology, 2011, 1 (7): 169-177.

[9] J. Chen, G. Hua, J.L. Jurat-Fuentes, M.A. Abdullah, and M. Adang, "Synergism of *Bacillus thuringiensis* toxins by a fragment of a toxin-binding cadherin". Proc. Nat. Acad. Sci. USA., 2007, 104: 13901-13906.

[10] T.H. Schuler, G.M. Poppy, B.R. Kerry, and I. Denholm, "Environmental risk assessment of transgene products using honey bee (*Apis mellifera*) larvae". Trends Biotechnol., 1998, 16: 168-175.

[11] S.A.A. Amer, A.M. Refaat, and F.M. Momen, "Repellent and Oviposition-Deterring Activity of Rosemary and Sweet Marjoram on the Spider Mites *Tetranychus urticae* and *Eutetranychus orientalis* (Acari: Tetranychidae)". Acta Phytopathologica et Entomologica Hungarica, 2001, 36 (1-2): 155-164.

[12] Z.L. Liu, Y.J. Xu, J. Wu, S.H. Goh, and S.H. Ho, "Feeding deterrents from *Dictamnus dasycarpus* Turcz against two stored-product insects". J. Agric. Food Chem., 2002, 50 (6):1447-1450.

[13] Y. Trongtokit, Y. Rongsriyan, N. Komalamisra, and L. Apiwathnasom, "Comparative repellency of 38 essential oils against mosquito bites". Phytother. Res., 2005, 19 (4): 303-309.

[14] A.A. Khan, H.I. Maibach, W.G. Strauss, and W.R. Fenley, "Vitamin B_1 is not a systemic mosquito repellent in man". Trans. St. Johns Hosp. Dermatol. Soc., 2005, 55 (1): 99-102.

[15] E. Deletre, M. Thibaud, C. Pascal, B. Denis, C. Andy, M. Chantal, B. Romain, and C. Fabrice, "Repellent, Irritant and Toxic Effects of 20 Plant Extracts on Adults of the Malaria Vector *Anopheles gambiae* Mosquito". PLoS One., 2013, 8 (12): e82103.

[16] R.N. Singh, M. Maheshwari, and B. Saratchandra, "Biocoenology and control of whiteflies in sericulture". Insect Science, 2005, 12 (6):401-412.

[17] K.I.M. Jeong-Kyu, K.A.N.G. Chang-Soo, L.E.E. Jong-Kwon, K.I.M., Young-Ran, H.A.N. Hye-Yun, and Y.U.N. Hwa-Kyung, "Evaluation of Repellency Effect of Two Natural Aroma Mosquito Repellent Compounds, Citronella and Citronellal". Entomological Research, 2005, 35 (2): 117-120.

[18] I. Ishaaya, and A.R. Horowitz, "Insecticides with novel mode of actions: Overview". pp. 139. In: Insecticides with novel mode of actions, Mechanisms and application. Eds., Ishaaya, I. and Degheele, D., Berlin. 1997.

[19] A.A. Assar, M.M. Abo El-Mahasen, M.E. Khalil, and S.H. Mahmoud, "Biochemical effects of some insect growth regulators on the house fly, *Musca domestica* (Diptera: Muscidae). Egypt. Acad. J. Biolog. Sci., 2010, 2 (2): 33-44.

[20] M.G.P. Patricia, V.P. Emmanuel, H.N. Thiago, and C.B.B.C. Luana, "Inhibitors from Plants: Biochemical Characteristics and Adverse Effects on Insect Larvae. Series: Insects and Other Terrestrial Arthropods: Biology, Chemistry and Behavior, Microbiology Research Advances". Nova Science Publishers. 2013.

[21] J. Taverne, "Malaria on the Web and the mosquito-repellent properties of basil". Trends in Parasitology, 2001, 17 (6): 299-300.

[22] D. Gilrein, "Pesticide advancements rise while risks drop: Features - Pest Control". Cornell University Cooperative Extension of Suffolk County. 2014.

[23] D.L. Mahr, and N.M. Ridgway, "Biological control of insects and mites: An introduction to beneficial natural enemies and their use in pest management". N. Central Reg. Ext. Publ., 481. 1993.

[24] M. Sarwar, "Frequency of Insect and mite Fauna in Chilies *Capsicum annum* L., Onion *Allium cepa* L. and Garlic *Allium sativum* L. Cultivated Areas, and their Integrated Management". International Journal of Agronomy and Plant Production, 2012, 3 (5): 173-178.

[25] M. Sarwar, "Integrated Pest Management (IPM) - A Constructive Utensil to Manage Plant Fatalities". Journal of Agriculture and Allied Sciences, 2013, 2 (3): 1-4.

[26] M. Sarwar, "The Killer Chemicals for Control of Agriculture Insect Pests: The Botanical Insecticides". International Journal of Chemical and Bimolecular Science, 2015, 1 (3): 123-128.

Author's Profile

1. Dr. Muhammad Sarwar, Principal Scientist, is going through 25th years of Service experience in Research orientated Department of Agriculture (16-05-1991 to 31-05-2001, Government of Punjab), and Pakistan Atomic Energy Commission (01-06-2001 to date).
2. Have 172 publications in National (60) and Foreign (112) Journals with suitable Impact Factor.
3. Award of Higher Education Commission of Pakistan "Post-Doctoral Scholarship-2006" for Post Doc., research work at Chinese Academy of Agricultural Sciences, Beijing, China.
4. Shield award, Letters of Appreciation, and Certificates of performance and honor granted from Chinese Academy of Agricultural Sciences, Beijing, China.
5. Awarded Gold Medal-2010 by Zoological Society of Pakistan (International) in recognition of research contributions in the field of Insect Science.
6. Granted Research Productivity Award-2011, by Pakistan Council for Science and Technology.
7. Included in Panel of approved Supervisor of Higher Education Commission (HEC), Pakistan.
8. Completed "Basic Management Course" organized by Pakistan Institute of Engineering & Applied Sciences (PIEAS), Islamabad, held from 31 January to 18 February, 2011.