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Review Article

Biopesticides: Mode of Action, Efficacy and Scope in Pest Management

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A B S T R A C T

Excessive and inappropriate use of synthetic chemicals has undeniably resulted in adverse and irreparable effects on the environment. Use of agrochemical caused contamination of soils, agricultural crops and groundwater; and the continuous dependence on chemical pesticides to manage pest problems has aggravated environmental decline and caused serious health effects on agricultural employees and rural communities. Pesticide residues also increase food safety fears and pose-trade inhibitions for export crops, since agrochemical significantly amassed in plant parts and exaggerated the morphological, anatomical, physiological and biochemical procedures of the plants and as such result into total quantity and quality produce deprivation. Therefore, the need to feed an ever-increasing global population combined with cumulative request for maintainable agricultural practices has fueled a noteworthy upsurge in demand for biopesticides. Biopesticides are ecological and offer exceptional aids all along the food value chain, and providing a lot of chances and merits to growers, buyers, dealers, consultants, retailers and consumers. Since centuries, various plant extracts have been used in crop protection and significant effects have been achieved. Under cold arid conditions of Zanskar Ladakh region, various biopesticides have been evaluated under field conditions against *Helicoverpa armigera* and *Agrotis epsilon* and a considerable control has been achieved too. Therefore, in this article, biopesticide types, application methods, dosage, and mechanism of action will be discussed. Further, uses of biopesticides enhance the pest control in an ecofriendly manner to maintain the production sustainability over long period of time without deteriorating the environment.

Keywords: Biopesticides, *Helicoverpa Armigera*, Insect Pests, IPM, Ladakh, Zanskar

Introduction

The use of agrochemicals in crop protection has immensely contributed to the success of Green Revolution, thus leaded to sustainable production of food, fiber, fodder and feed (Bhushan et al., 2011). During the last four decades of chemicalisation and agricultural intensification, no doubt the production has doubled many folds but simultaneously resulted in several problems like pesticide residues in food stuff, environmental pollution, imbalance of ecological equilibrium (pollinators and other beneficial insects), and resurgence of minor pests and pathogens (Mukherjee et al., 2013). Management of pests, a term which comprises insects, pathogens, weeds and rodents, etc., will remain to play a serious role in supporting production and efficiency in Indian agriculture. The use of synthetic chemical pesticides had been augmentedextensively for dipping the assessed 45% gross crop loss due to pests and diseases, amounting to around Rs. 290 billion per annum (Gupta et al., 2013). Hundreds and thousands types of chemicals are used for agricultural intensification to feed an ever growing population. In fact, the pest induced loss is on the rise despite increasing usage of pesticides.

Providentially, consciousness of the undesirable effects of these chemicals have compulsory agriculturists to shift focus to more dependable, maintainable and environment friendly methods of insect pest control, "the biopesticides". The biopesticides are pesticides derived from natural materials like animals, plants[1], bacteria, fungi[4], and certain minerals. These are aimed to suppress or reduce the noxious pests irrespective of any side effects to the humans and environment. In spite of the demanded efficacy, their use, however, has continued very squat due to a number of socio-economic, technological, political and institutional restraints(Chandler et al., 2011). However, increase in revenue levels due to an increasing economy coupled with cumulative consciousness of severe health related effects of chemical pesticides has augmented the request of organic food. In view of demand and the government's exertions to alleviate climate change, biopesticides are going to play an imperative role in pest management programs (Gupta et al., 2013). Though the use of chemical efforts in agriculture is unavoidable to meet the growing request for food in the world, there are occasions in selected crops and niche areas where organic production can be fortified to trap the domestic export market. The other important problem caused by the excessive and inappropriate use of chemical pesticides concerns the presence of pesticide residue in food (Yankanchi and Gadache, 2010). Many of the pesticides currently being used have a tendency to survive in plants for a long time and they also go into the food chain. The problem of pesticide residue is already a serious threat to environment and human health. It is clear that the excessive use of chemical pesticides in agriculture is a serious cause of concern. It is therefore imperative that substitute environmental friendly approaches of plant protections are accepted, such as integrated pest management (IPM) methods, comprising the use of biofertilizers and biopesticides (Kawalekar, 2013).[11]

Pest and Pesticides

Pesticides in general are substances designed/formulated to kill, repel, or control certain forms of plant or animal life that are considered to be pests. The pesticides include herbicides, insecticides, fungicides, bactericides, and rodenticides. Because of the prevalent use of agricultural chemicals in food production, people are bare to squat levels of pesticide residues through their diets. Pest management methods have changed over years and inorganic chemical were swapped by synthetic organic chemicals, and now biopesticides establish a noteworthy part of pest management technology. As a notion the synthetic chemicals had remained as important pest management components, but due to its adverse impacts, the new and equally important tools in pest management with microbial pesticides[1] and transgenic crops[2] are likely to play important crop protection roles (Prabhat et al., 2014).

Agriculture has been identified as the largest non-point source of water pollution, but it can also provide methodologies to even prevent pollution. In their involvement, agricultural green chemistry is bioremediation process of organic waste-containing aqueous solvents (Prabhat et al., 2014). Pesticides are the only toxic constituents released deliberately into our environment to execute living things. The use of toxic pesticides to accomplish pest problems has become a common rehearsal around the world, used almost universally not only in agricultural fields, but also in homes, parks, schools, buildings, forests, and roads. Therefore, it is problematic to find anywhere where pesticides are not used from the can of bug spray under the kitchen sink to the airplane crop dusting acres of farmland; world is occupied with pesticides. In addition, pesticides can be found in the air we breathe, the food we eat, and the water we drink. Due to the blind use and heavy exposure of living and non-living systems to toxic chemicals huge problems and unavoidable issues has raised in past few decades, as these toxic chemicals are linked to our every system, causing headaches, nausea, cancer, reproductive harm, and endocrine disruption. Therefore, the need for an alternative to replace these synthetic chemicals is of great thrust and for that the only option left is biopesticides to provide security to all systems on earth.

Effects of Pesticides on Living System

Acute Effects

Acute effects are short term or immediate effects and they include nerve, skin, and eye irritation and damage,

headaches, dizziness, nausea, fatigue, and systemic poisoning. This can sometimes be dramatic, and even occasionally fatal.

Chronic Effects

The chronic effects are long term effects and may occur years after even minimal exposure to pesticides in the environment, or result from the pesticide residues which we ingest through our food and water (Biological magnification).

Biopesticides - Safety to Living System

Generally, biopesticides are pesticides that include insect pheromones, plant extracts, oils, plant growth regulators and insect growth regulators (Gupta and Dikshit, 2010). Microbial pesticides includes bacteria, virus, fungus, and other less common microorganisms, having huge benefits like less toxicity, quick biodegradability and target to specific pest and maintain ecological balance. Since the field of biopesticides is profound; accordingly they are a source of both sanguinity worry and a marvelous amount of work and research stirring in this field, but like other green chemistry solutions, emergent safe, operative biopesticide products needs holistic thinking and multi-disciplinary methods to founding safety, which is a contest for the biopesticide industry(Prabhat et al., 2014). It is important to note that biopesticides fall along a spectrum of toxicity. At one end biopesticides are extremely narrow in focusing single species in a specific window of its life cycle while at other end biopesticide are wider in effect especially when security to living system is concerned. Biopesticides are utterly benign in their human and environmental effects, and raise almost none human and ecosystem impact compared to conventional pesticides (Byrappa et al., 2012). The organisms (Virus, fungi, bacteria etc.) are mass-produced using either a submerged liquid fermentation or solid-substrate (microbes produced on a solid food source) fermentation processes highly specific to a bio-pesticide organism, and are often developed in a custom designed medium (Venkatashwarlu, 2008). Formulations create an end product by blending the microbial component with carriers and adjuvant for better protection from unfavorable environments, enhanced survival of the bio-agent, controlled rates of release, as well as improved bioactivity, shelf life, and stability.

Scope of Biopesticides

Biopesticides are anything that kills a pest and is biological in origin (that is, viruses, bacteria, pheromones, plant or animal compounds), or simply origin of the active ingredient of a biopesticide is natural not synthetic (USEPA, 2008). They are highly specific affecting only the targeted pest or closely related pests and do not harm humans or beneficial organisms, while chemical pesticides are broad spectrum and known to affect non-target organisms including predators, parasites and other beneficial organisms (Kundoo et al., 2018). The outstanding feature of biopesticides is situation friendliness and easy biodegradability, thereby subsequent in lower pesticide residues and mainly evading pollution glitches related with chemical pesticides (Greaves and Grant, 2011). Further, use of biopesticides as a component of integrated pest management (IPM) programs[3] can greatly decrease the use of conventional (chemical) pesticides, while achieving almost the same level of crop yield. However, operative use of biopesticides strains understanding of a great deal about managing pests expressly by farmers. In terms of production and commercialization also, biopesticides have an edge over chemical pesticides like squat research outlay, faster rate of product development as well as flexible registration procedure(Prabhat et al., 2014). The biopesticides market is growing very rapidly, and market value is estimated to reach more than billions in future. However, the complete growth rate of biopesticides is predictable to be about 10% per annum for the next 5 years (Sinha and Biswas, 2008).

Biopesticides and Mode of Action

Although the biochemical pesticides are closely related category to conventional chemical pesticides, but are distinguished from synthetic chemicals by their non-toxic mode of action toward target organisms (Dar and Padder, 2016) and their natural occurrence. The active ingredient can be a single molecule or a mixture of molecules, such as a naturally happening mixture including a plant essential oil, or a mixture of very anatomically alike molecules called isomers in the case of insect pheromones. While all active ingredients of biochemical pesticides occur in nature, the active ingredient in the product may be a synthetic analogue to the naturally occurring substance. This is often necessary to make a viable product and/or process, such as with insect pheromones. As many of the active ingredients in this category of biopesticides are synthetic, the full range of green chemistry principles should be applied to the development of the active ingredient and the biochemical pesticide product (USEPA, 2008).

Insect Pheromones

The insect pheromones are chemicals employed by an insect to interconnect with other members of the same species. Mechanically, these chemicals are often very comparable to substances used in flavors and fragrances. The pheromones are a subset of a broader category called semiochemicals[5] used for pest management.[6] A semi chemical is definite as a message-bearing substance produced by a plant or animal, or a synthetic analogue of that substance, which arouses behavior response in individuals of the same or other species (Chandler et al., 2011). The semi chemicals are used for various functions comprising attracting others to a known food source or trail, locating a mate, or transfer an alarm. Insect sex pheromones

are used in pest management. The insect pheromones themselves do not kill a target pest. When employed for pest management, two common uses are to entice an insect to a trap comprising a lethal pesticide or to disturb mating. With mating disruption, proportionately large concentrations of the sex pheromones are present in the air, thus confusing the males and decreasing their success at locating a female with which to mate. The pheromones can also be used to monitor pest populations as part of larger integrated pest management (IPM) systems, particularly to determine appropriate timing and application of pesticides (Karen et al., 2009).

Plant Extracts and Oils

The plant extracts and oils are specific chemicals or mixtures of chemical components derived from a plant. This category of biopesticides is much more diverse in composition, target pest, and mode of action than insect pheromones discussed above (Byrappa et al., 2012). The plant extracts and oils are most often used as insecticides, but can also be used as herbicides. The mode of action varies greatly from product to product. Where sex pheromones straight interject the reproductive cycle of insects, plant extracts and oils frequently act less directly and precisely. Some botanical extracts such as floral essences attract insects to traps. Others such as cayenne can be employed as deterrents. Others, such as lemongrass oil, strip the waxy coating off leaves of weeds to reason dehydration. Others coat the pest causing suffocation, and still others augment the natural immune system of a crop (Kawalekar, 2013).

Plant Growth Regulators

The plant hormones and plant growth regulators are chemicals that alter the growth of a plant or plant part, or promote certain biological changes in the plant. Plants produce hormones naturally, while humans apply growth regulators to the plants (Karen et al., 2009). The plant growth regulators may be synthetic compounds (for example: IBA and Cycocel) that imitator naturally occurring plant hormones, or they may be natural hormones that were mined from plant tissue (for example: IAA). According to the Florida Department of Agriculture and Consumer Services, a plant growth regulator is demarcated as any substance or mixture of substances proposed, through physiological action, to quicken or impede the rate of growth or maturation or for otherwise varying the behavior, of ornamental or crop plants, or the produce thereof, but does not contain substances proposed as plant nutrients, trace elements, nutritional chemicals, plant inoculants, or soil amendments (Yankanchi and Gadache, 2010).

Insect Growth Regulators

The insect growth regulators are chemical compounds that alter the growth and development of insects. Thus, they are specific to the control of insect pests. There are three key types of insect growth regulators, each with a distinct mode of action. Juvenile hormone-based insecticides disrupt immature development and the emergence of an adult. Preciseness interfere with normal function of the glands that produce juvenile hormone, thereby indirectly preventing the emergence of a reproductive adult (Yankanchi and Gadache, 2010). Chitin synthesis inhibitors limit the ability of the insect to produce a new exoskeleton after molting. Thus, chitin synthesis inhibitors leave the insect undefended from the rudiments and from prey, drastically tumbling its likelihoods of existence(Yankanchi and Gadache, 2010).

Microbial Pesticides

The microbial pesticides originate from logicallyhappening or genetically changed bacteria, fungi, algae, viruses or protozoans. They overwhelm pests either by creating a toxin precise to the pest, causing ailment, averting establishment of other microorganisms through competition, or various other mechanism of action. For all crop types, bacterial biopesticides privilege about 74% of the market; fungal biopesticides, about 10%; viral biopesticides, 5%; predator biopesticides, 8%; and "other" biopesticides, 3% (Thakore, 2006). At present, there are around 73 microbial active ingredients that have been recorded by the US EPA. The registered microbial biopesticides contain 35 bacterial products, 15 fungi, 6 non-viable (genetically engineered) microbial pesticides, 8 plant incorporated protectants, 1 protozoan, 1 yeast and 6 viruses (Kawalekar, 2013).

Bacterial Biopesticides

The bacterial biopesticides are the most communal form of microbial pesticides. They are typically used as insecticides, although they can be employed to control unwanted bacteria, fungi or viruses as well. As an insecticide, they are usually precise to separate species of moths and butterflies, as well as species of beetles, flies and mosquitoes. To be active, they must come into interaction with the target pest, and may require ingestion to be effective (Kawalekar, 2013).

Fungal Biopesticides

The fungal biopesticides can be used to control insects, plant diseases including other fungi or bacteria, nematodes, and weeds. They are often parasitic or produce bioactive metabolites such as enzymes that dissolve plant walls. The mode of action varies and depends on both the pesticidal fungus and the target pest. *Beauveria bassiana* spores germinate, grow, and proliferate in the insects' body, producing toxins and draining nutrients to cause insect death. Trichoderma is a fungal antagonist that grows into the main tissue of a disease-causing fungus and secretes enzymes that degrade the cell walls of the other fungus, then consumes the contents of the cells of the target fungus and multiplies its own spores (Kawalekar, 2013).

Table 1.Effect of neem based pesticides on Helicoverpa armigera and Agrotisypsilon at Zanskar, Ladakh 2019-2020

Product name	Biopesticide present	Target pest	Crop	Concentration applied	Time of application	Method of application	Spray Interval	Damage (%)		% recovery over control
								Treatment	Control	
Astha Killer	Azadirachtin 1%	Helicoverpa armigera	Pea	1 ml/3 ltr water	Morning /or evening	Spraying over crop foliage	20 days	23.43	34.48	32.04
Organeem	10000 ppm Neem oil	Pieris brassicae	Cabbage		-do	-do	15 days	6.75	18.25	63.01
Nano shooter	Organic extract +micronutrient	Aphids	Cabbage	0.25/ ltr water	-do	-do	-do	2.65	6.98	62.03
Nano Laser	Organic extract +micronutrient	Plutella xylostella	Cabbage	0.25 ml/ltr	-do	-do	-do	4.23	10.78	60.70
Nano Laser	Organic extract +micronutrient	Onion Maggots	Onion	0.25 ml/ltr	-do	-do	-do	2.89	2.99	3.34
Astha Killer	Azadirachtin 1%	Agrotis epsilon	Pea	1 ml/3 ltr water	-do	-do	20 days	11.71	15.09	22.39
Astha Killer	Azadirachtin 1%	Gall wasp	Willow	1 ml/3 ltr water	-do	-do	-do	6.21	7.04	11.78
Note: the above data is from experimental trials conducted during 2019-2020 at KVK-Zanskar, Ladakh SKUAST-K, Srinagar (Dar S A 2019-2020).										

Viral Biopesticides

The use of viruses as potent biocontrol agent (baculoviruses) are considered to be future of biopesticides because of their obligatory nature and host specificity. Unlike other members of this category, they are not considered living organisms, but rather parasitically replicating microscopic elements (USEPA, 2008). Baculoviruses are tremendously small and are self-possessed mainly of double-stranded DNA required for the virus to create itself and reproduce. Because this genetic material is simply demolished by exposure to sunlight or by circumstances in the host's gut, an infective baculovirus particle (virion) is threatened by protein coat called a polyhedron. Two main families of baculoviruses contain granulosis virus and nucleopolyhedrosis virus. They differ in the number and structure of the protective protein coat and are both relatively large and complex in structure in comparison to many other types of viruses. However, viruses are diverse in nature and few cause huge disease in honey bees[15], but few species are very beneficial for the management of veracious pests e.g. Gypsy moth, Pieris brassicae, and cutworm.

Other Microbial Biopesticides

The use of other organisms like protozoa, nematodes etc. are used in different parts of the world. The nematodes are successfully used to control insect pests like DBM, *Helicoverpa armigera* etc. Protozoa (microscopic single-celled organisms) are rarely used as biopesticides. As of 2002, there was only one insecticidal protozoan registered with the EPA. Macroscopic predators are not regulated as biopesticides, and are outside the scope of this study. Nematodes are microscopic worms that are typically parasitic and commonly used as insecticides.

Biopesticide Formulations

A registered biochemical or microbial pesticide contains one or more active ingredients from the categories described above. The active ingredient(s) is primarily liable for the pesticide claims. The product formulation contains one to dozens of other ingredients besides active ingredients called inerts. These inert material are often treated as benign (Prabhat et al., 2014). On the contrary, inerts are vital components required to form an efficient product and therefore the toxicity profiles of inerts vary widely. Moreover, inert ingredients can have serious potential health and ecosystem impacts and may include endocrine disrupting chemicals, allergens and other chemicals of concern. Biopesticide products (including beneficial insects) are now accessible commercially for the control of pest and ailments. The complete aim of biopesticide investigation is to make biopesticide products obtainable at farm level at an inexpensive price, and this would become a likely tool in the combined pest management plan. Moreover, biopesticide research is still going on and more research is desirable in many features comprising bioformulation and areas such as commercialization. There has been a considerable renewal of commercial attention in biopesticides as established by the significant number of agreements between pesticide companies and bioproduct companies which permit the development of actual biopesticides in the market. The usefulness of bioinsecticides as environmentally friendly pest control tools to be integrated, in combination or rotation, with chemicals in pest management programs will prove to be an important step towards green farming concept in India.

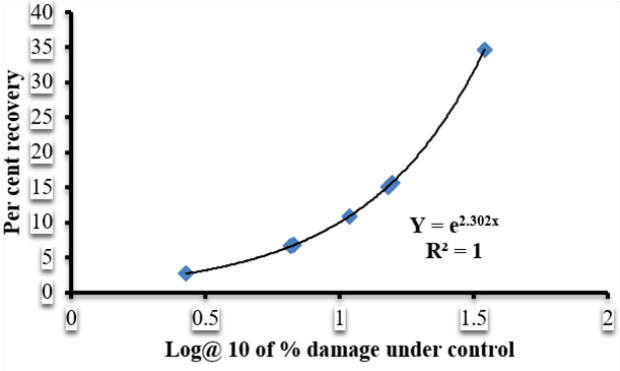

Figure 1.Curve representing the per cent recovery over control under field conditions of Zanskar Ladakh, 2019-2020

Figure 2.Cabbage (Brassica oleracea var. capitata) damaged by Diamondback moth (Plutella xylostella) at Budgam under no treatment

Figure 3.Cabbage (Brassica oleracea var. capitata) damaged by Cabbage aphid (Brevicoryne brassicae) at Budgam with no treatment given

Figure 4.Mustard (Brassica rapa) damaged by Diamondback moth (Plutella xylostella) at Budgam under no treatment

Figure 5.Mustard (Brassica rapa) damaged by Mustard aphid (Lipaphis erysimi) at Budgam under no treatment

Figure 6.Cabbage (Brassica oleracea var. capitata) damaged by at Budgam (village: Jawalapora) using Neem as treatment

Figure 7.Cabbage (Brassica oleracea var. capitata) field damaged by at Budgam (village: Jawalapora) using Neem as treatment

Fruit Fly Management

Fruit flies are very dangerous pests to fruits and vegetables (Mir et al. 2014, Mir et al. 2015). Rahman et al. (2019) from Bangladesh conducted a study over the use of three biopesticides viz Spinosad, Abamectin and L. muscarium both alone and their different combination against fruit flies and found these chemicals significantly useful against the cucurbit fruit fly infesting bitter gourd. The individual application of Spinosad had provided moderate efficacy. However, when, it was applied by admixing with L. muscarium, the combination was recorded as the most effective treatment considering the reduction of percent fruit infestation, increasing the fruit yield and decreasing the infested fruit yield.

Summary and Conclusion

We highlight that biopesticides are a set of tools whose applications will aid farmers transfer from consumption of toxic synthetic chemical pesticides into an era of truly bearable agriculture in an ecofriendly method. For the sustainable crop production the biopesticides are only solution to save heath as well as environment. Biopesticides support farmers to move from their current chemical addiction to organic agriculture as tool for the new epoch. It is pragmatic that biopesticides played a noteworthy role, and if adapted fully will play a noteworthy role in the process maintainable crop production, in that they bid powerful tools to create a new group of good health also maintenance of species as well. Biopesticides are the only alternative to replace toxic and lethal chemicals, which are under ever increasing scrutiny. At present due to blind usage of toxic chemical in agriculture, the issues of secondary pest outbreak, resistance, pollution and public health hazards, like cancer, tumor, lung infection, and much has spread at an alarming rate in the community. The Ladakh region is an organic zone and most of the farmers prefer to follow organic practices for crop production. Besides many crop protection practices adopted by local farmers, the biopesticides have been newly introduced and results obtained were satisfactory. In order to tackle these issues the application for biopesticides was found effective to control overall crisis in community.

References

1. Dar SA, Nisar AD, Mudasir AB et al. Prospects, utilization and challenges of botanical pesticides in sustainable agriculture. *International Journal of Molecular Biology & Biochemistry* 2014; 1: 1-14.
2. Dar SA, Wani AB, Kandoo AA. Genetic engineering and insect resistance. *Journal of Entomology and Zoology Studies* 2017b; 5(3): 1175-84.
3. Dar SA, Wani AR, Sofi A et al. IPM for brinjal shoot and fruit borer (Leucinodes Orbonalis)-A review. *Indian*

Journal of Entomology 2017c; 79 (2): 130-7.
4. Dar SA, Rather BA, Kandoo AA. Insect pest management by entomopathogenic fungi. *J. Entomol. Zool. Stud.* 2017a; 5: 1185-90.
5. Dar SA, Wani ABR, Rather BA, et al. Biochemical basis of resistance in brinjal genotypes against shoot and fruit borer (Leucinodes Orbonalis, Guenee). *Chem Sci Rev Lett.* 2017d; 6(22): 1062-73.
6. Dar SA, Padder SA, Wani AR, et al. Evaluation of combined options for management of brinjal shoot and fruit borer (Leucinodes orbonalis) in Kashmir. *Journal of Experimental Zoology* 2015; 18(1): 359-65.
7. Dar SA. Department of Entomology, SKUAST-K, Srinagar Kashmir. 2019.
8. Dar SA. Department of Entomology, KVK-Kargil Ladakh, SKUAST-K, Srinagar J&K. 2020.
9. Dar SA, Padder SA. Toxins and targets of insecticidal genes of entomopathogenic bacteria: a review. *Journal of Pure and Applied Microbiology* 2016; 10(2): 1089-99.
10. Kundoo AA, Dar SA, Mushtaq M, et al. Role of neonicotinoids in insect pest management: A review. *Journal of Entomology and Zoology Studies* 2018; 6(1): 333-9.
11. Mahdi SS, Hassan GI, Samoon SA et al. Bio-Fertilizers in Organic Agriculture. *Journal of Phytology* 2010; 2(10): 42-54.
12. Mir SH, Ahmad SB, Dar SA et al. Hemilea malaisei Hering (Diptera: Tephritidae): The first record from India. *Entomological News* 2017; 127(2): 151-3.
13. Mir SH, Dar SA, Mir GM et al. Biology of Bactrocera cucurbitae (Diptera: Tephritidae) on cucumber. *Florida Entomologist* 2014; 97(2): 753-8.
14. Rahman MM, Howlader MTH, Islam KS et al. Efficacy of three biopesticides against cucurbit fruit fly, Bactrocera cucurbitae Coquillett (Diptera: Tephritidae) and yield of bitter gourd. *Journal of Bangladesh Agricultural University* 2019; 17(4): 483-9.
15. Ullah A, Gajger Tlak I, Majoros A et al. Viral impacts on honey bee populations: a review. *Saudi Journal of Biological Sciences* 2020.