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Application of Insect Growth Regulators (IGRs) as Biopesticides for Sustainable Agriculture

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ABSTRACT

The application of conventional pesticides is underlined by many negative externalities including environmental degradation and pest resistance. Consequently, use of biopesticides as alternative agrochemicals is recommended to meet sustainable development goals. Insect growth regulators (IGRs) are biochemical biopesticides. Actually, Biochemical biopesticides are compounds (or exact synthetic analogue) of natural origin possessing active ingredients that control pest in a way that are nontoxic to the target pest, the environment and humans. So, insecticides with growth regulating properties may adversely affect insects by regulating or inhibiting specific biochemical pathways or processes essential for insect growth and development. Ecdysoids and Juvenoids (JH mimics) are among the most promising IGRs. Ecdysoids are synthetic analogues of natural ecdysone and when applied in insects, kill them by formation of defective cuticle. Juvenoids (JH mimics) are synthetic analogues of Juvenile Hormone (JH). Juvenoids have anti-metamorphic effect on immature stages of insect. Along with this, Anti JH or precocenes which act by destroying corpora allata and preventing JH synthesis also act as IGR. In this way, Insect Growth Regulators are potential substitute of insecticides that could be commercially used.

Keywords : Biopesticides, Insect growth regulators (IGRs), Insect Endocrine System, Integrated Pest Management (IPM)

INTRODUCTION

During the Green revolution, achieving high crop yields at any cost was the ultimate goal. Now, the emphasis is on sustainable agriculture that is increasing yields without harming the environment. Hence, it is encouraged to use 'Integrated pest management (IPM)' approach in pest control. Emphasis of IPM is to grow a healthy crop with the least possible disruption to agro-ecosystems and

encourages natural pest control mechanisms. To promote the use of biopesticides rather than chemical pesticides is an integral part of IPM. Biopesticides are competitive subclass of pesticides dealing with naturally occurring organisms or compounds that suppress the growth and proliferation of pests' population by diverse mechanisms of action, excluding those that interfere with pests' nervous systems. Microbial biopesticides, biochemical biopesticides, and plant-incorporated protectants (PIPs) are the well-known categories of biopesticides [1], [2].

Basically, Insect Growth Regulators (IGRs) are biochemical pesticides comprising compounds interfering with growth, development and metamorphosis of insects. IGRs include synthetic analogue of insect's hormones such as ecdysoids and juvenoids and non- hormonal compounds such as precocenes (Anti JH) and chitin synthesis inhibitors [3]. The, action of IGRs however, should not be confused with other synthetic insecticides, such as organophosphates and carbamates, since these chemicals interfere with other physiological processes but do not regulate the normal development of insects [4]. So, for understanding the mechanism of IGRs action having the basic idea of insect's endocrine system is very important.

INSECT'S ENDOCRINE SYSTEM

In insects, prothoracic glands are the largest and chief endocrine glands found in the prothorax, just behind the head. These glands secrete **ecdysteroids**, a group of closely-related steroid hormones (including ecdysone) that stimulate synthesis of chitin and protein in epidermal cells and trigger a cascade of physiological events that culminates in moulting. Thereby, ecdysteroids are often called "moulting hormones". Secretion of ecdysteroids by prothoracic glands is stimulated by a chemical messenger, **prothoracicotropic hormone** (PTTH). PTTH is a peptide hormone secreted by the corpora cardiaca, a pair of neurohemal organs located on the walls of the aorta just behind the brain. Further, corpora cardiaca release their store of PTTH only after they receive a signal from neurosecretory cells in the brain. The corpora allata, another pair of neurohemal organs, lie just behind the corpora cardiac which synthesize **juvenile hormone** (JH). JH is a compound that inhibits development of adult characteristics during the immature stages and promotes sexual maturity during the adult stage. Neurosecretory cells in the brain regulate activity of the corpora allata [5]. JH I, JH II, JH III and JH IV have been identified in different groups of insects. The concentration of JH decreases as the larva grows and reaches pupal stage. JH I, II and IV are found in larva while JH III is found in adult insects and are important for development of ovary in adult females [6].

DISCOVERY OF INSECT GROWTH REGULATORS (IGRs)

In 1956, when juvenile hormone (JH) was isolated from the abdominal crude extract of the male Cecropia moths *Hyaloptora cercopia* (L.) then, it was assumed to use such isolates, kind of IGRs in insect control. Interestingly, application of the hormone prevented metamorphosis and subsequent multiplication of insect. However, it was not noticed until the discovery of 'paper factor' in 1965 because the 'paper factor' led to understanding of the potential use of JH in insect development. Researchers at Harvard observed that cultures of the linden bug, *Pyrrhocoris apterus* L., which originally came from Czechoslovakia, had low egg hatch rates and that supernumerary larva, rather than adults, were formed. Their investigations later showed that the abnormality observed was caused by the material in the paper towels used in the rearing jars. The active component of the paper towel, which was later identified as juvabione, came from the balsam fir, *Abis balsamea* (L.), the main pulp tree used in the United States paper industry (newspapers , magazines, etc.). Juvabione is a methyl ester of domatuic acid proven to be a very specific juvenile hormone mimic

of the hemipteran family Pyrrhocoridae [4], [7]. The discovery of this highly specific substance led to industrial interests in JH as a tool in developing IGRs.

MAJOR GROUPS OF IGRs USED IN PEST MANAGEMENT

IGRs can be grouped according to their mode of action, as follows: chitin synthesis inhibitors (i.e. of cuticle formation) and substances that interfere with the action of insect hormones (i.e. JHs, ecdysteroids).

CHITIN SYNTHESIS INHIBITORS (CSIs)

The insects cuticle serve as an interface between the living animal and its environment and also forms the exoskeleton, supporting the lining of gut, respiratory system, reproductive ducts, and some glands ducts [4]. Because CSIs interfere with the polymerization of chitin, this mode of action has been targeted for control of several different insect pests. CSIs cause abnormal deposits of endocuticle that accumulate during moulting, specifically uridine diphospho-N-acetylglucosamine monomers thereby preventing chitin synthesis [4]. The first chitin synthesis inhibitor introduced into the market as a novel insecticide was benzoylphenylurea, diflubenzuron [6]. Benzoylphenyl ureas inhibit chitin synthesis by blocking the activity of enzyme chitin synthetase. As a result several developmental abnormalities appeared in emerging insects such as- disruption of moulting, displacement of mandibles and labrum, adults fail to escape from pupal skin and dies and ovicidal effects. Chitin synthesis inhibitors have been successfully used against pests belonging to Lepidoptera, Coleoptera and Diptera [8]. Diflubenzuron and its derivatives were effective against insect pests and mites infesting field crops, and were relatively harmless to beneficial insect species. Burofezin was another CSI, used against Homopteran pests. Lefunuron, an orally administered CSI was also used against fleas [9].

ECDYSTEROIDS OR MOULTING HORMONE ANALOGUES (MHAs)

The nonsteroidal synthetic analogues of moulting hormone or ecdysone are ecdysoids while steroidal one termed as ecdysteroids. Ecdysone is responsible for cellular programming and in together with JH, initiates moulting process. When analogues of ecdysone applied in insects, kill them by formation of defective cuticle. The development processes are accelerated bypassing several normal events resulting in integument lacking scales or wax layer. Chemically, ecdysoids are bisacylhydrazines. Some of the popular commercially available MHAs are Tebufenozide, Methoxyfenozide, Halofenozide were found effective against various lepidopterous insects [7].

ANTIMOULTING HORMONES ANALOGUES (AMHAs)

The compounds that antagonize the action of moulting hormone and juvenile hormone are named as antimoulting hormone analogues (AMHAs) and antijuvenile hormone analogues (AJHAs) respectively. Chemically AMHAs are azosterols and non-steroidal compounds; they act by antagonizing the conversion of phytosterol to cholesterol which is required as a base for the synthesis of ecdysone in insect. Thus, the moulting hormone concentration is affected and consequently, moulting is delayed [10].

JUVENILE HORMONES ANALOGUES (JHAs)

The synthetic analogues of juvenile hormones are known as juvenoids which cause morphogenetic, gonadotropic and diapause disrupting effects in insects. Small amount of JH is required for the ovarian maturation or vitellogenesis. However, exogenous application of higher JH concentration on adult females reduces their eggs unviable and thus eggs fail to hatch. If, somehow they hatch the effect is revealed into larval instar which is unable to metamorphose into adult. Exogenous application of JH on diapausing pupae activates prothoracic gland and prevent it from

entering into diapause thus, disrupting the insect homeostasis [11], [7].

ANTI JUVINILE HORMONES OR PRECOCENES

Anti- juvenile hormones are also termed as 'precocenes' because of their ability to induce precocious metamorphosis of the immature insects. Precocenes induced variety of physiological and behavioural changes including precocious metamorphosis of the immature stages, sterilization of adult females, diapause induction and inhibition of sex pheromone production [12]. Anti JHs act by destroying corpora allata and preventing JH biosynthesis when treated at immature stage of insect, causing skip of one or two larval instars and thus, turn into tiny precocious adults [10].

FUTURE PROSPECTS AND CONCLUSION

Insect growth regulators have great potential to be commercially utilized fir insect control. JHAs and CSIS among IGRs can be used judiciously as many commercial formulations of these are available to strengthen IPM. Because of the mode of action of IGRs, they become less prone to cross-resistance while, low mammalian toxicity, biodegradability and specific nature of these compounds make them eco-friendly. Though, stage-specificity of JHAs may limit their use under field condition. However, there are certain factors like costlier synthesis, environmental instability and narrow host range which limit their industrial applications.

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