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Effects of phyto-ecdysteroids on growth and development of insects

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Introduction

The ecdysteroid (insect moulting hormone) was first isolated by Butenandt and Karlson (1954) from *Bombyx mori* (Linnaeus) and its structure was finally elucidated through X-ray crystallography by Huber and Hoppe (1965). Ecdysteroid analogues derived from plants are called phytoecdysteroids (PEs). When insects feed the plants with PEs they will prematurely moult, loose weight or suffer from other metabolic damage and die. Nakanishi *et al.* (1966) were first isolated the phytoecdysteroids (Ponasterones A, B and C) from the plume pine (*Podocarpus nakaii* Hayata). Ecdysteroids have been detected in 27 families of the Pteridophyta, 10 families of Gymnosperm and 74 families of Angiosperm (Dinan *et al*., 2001). Approximately 6 per cent of all plant species synthesize phytoecdysteroids (Arif*et al*., 2022).

Mode of action of phytoecdysteroids

In insects, 20-Hydroxyecdysone (20-HE) acts through the ecdysone receptor (nuclear receptor). The ecdysone receptor is a non-covalent heterodimer of two proteins *viz*., the Ecdysone Receptor protein (EcR) and Ultra Spiracle Protein (USP). EcR must be dimerized with a USP for high-affinity ligand binding. The binding of ecdysone to receptor leads to the activation of ecdysone responsive genes and many other genes. Which ultimately causes physiological changes that result in ecdysis. The ecdysone receptor also binds and activated by phytoecdysteroids. Thus, phytoecdysteroids can mimic 20-hydroxyecdysterone of insects, bind insect ecdysone receptors and can elicit the same responses. This ultimately causes physiological changes that result in premature ecdysis (Chaubey, 2017).

Estimation of phytoecdysteroids

Phytoecdysteroids can be extracted from the dried plant materials then estimated by several techniques *viz*., reversed phase thin layer chromatography, high-performance liquid chromatography, column chromatography, supercritical fluid chromatography, nuclear magnetic resonance followed by mass spectrometry. High-performance liquid chromatography is the most commonly used method for separation of ecdysteroids given by CSIRO, Australia, as described by Kerkut and Gilbert (1985).

Effects of phytoecdysteroids on insects

Inhibition of pupation and adult emergence: **Rharrabe *et al.* (2010)** found that no cumulative pupation and adult emergence observed in larvae of *Plodia interpunctella* treated with Makisterone A. **Tatun *et al.* (2018)** concluded that the red rust flour beetle, *Tribolium castaneum* larva injected with 20-HE @ 300 ng/insect during last larval instar showed morphological abnormalities in pupal and adult stage. **Rharrabe *et al.* (2019)** reported that the larva of *T. castaneum* feeding on

wheat flour mixed with 1200 ppm 20-HE recorded adult emergence up to 30 per cent, whereas it was cent per cent in control. **Radi *et al.* (2020)** concluded that cotton leafworm, *Spodoptera littoralis* larva fed castor leaves sprayed with phytoecdysteroid fraction @ 250 µg/µL for 4 days were unable to complete their pupation.

Reduction in fecundity and fertility: Radi *et al.* (2011) found that ecdysterone extracted from bugleweed, *Ajuga iva* plant had significantly reduced fecundity (75%), while cyasterone from the same plant caused reduction in fecundity (50%) of *Bemisia tabaci.* They also found that ecdysterone significantly reduced egg fertility (44%) as compared to control. **Sun *et al.* (2015)** revealed that *Plutella xylostella* treated with 20-HE @ 0.5 mg/ml recorded lowest fecundity (128.6 ± 6.4).

Reduction in energy reserves and body weight: Exposure of Indian meal moth, *Plodia interpunctella* larva to 20-HE decreased protein, glycogen and lipid content in larva as compared to untreated larva **(Rharrabe *et al.*, 2009)**. Ingestion of 20-HE also caused significant decrease in protein content and inhibited alpha-amylase activity in *T. castaneum* larva **(Rharrabe *et al.*, 2019)**. **Radi *et al.* (2020)** concluded that percentage of larval weight gain was reduced in first instar of *S. littoralis* after feed on *A. iva* crude leaf extract treated feed.

Cannibalism: Rharrabe *et al.* (2009) observed that larva of *P. interpunctella* fed on wheat flour mixed with 20-HE @ 50 ppm showed 26.7 per cent cannibalism, whereas the rate of cannibalism in control never exceeded 7 per cent.

Mortality: Colorado potato beetle, *Leptinotarsa decemlineata* S. larva feeding on potato leaves sprayed with 0.01% 20-HE suffered 53.3 per cent mortality **(Zolotar *et al.*, 2001)**. **Rharrabe *et al.* (2010)** recorded the highest mortality (84%) of *P. interpunctella* larva @ 200 ppm concentration of Makisterone A followed by Ponasterone A (64%) after 22 days. **Radi *et al.* (2011)** observed 65 per cent mortality of persea mite (*O. perseae*) after treatment of *A. iva* leaf extract.

Feeding deterrence: Spray application of 20-HE @ 5 g/L inhibited the feeding of Japanese beetle, *Popillia japonica* N. adults in soybean leaves under choice and no-choice assays **(Russell *et al.*, 2017)**.

Improvement of silk yield: Oral administration of phytoecdysteroids from chaff-flower, *Radyx achyranthes* to larva of *B. mori* at 48 hrs of 5th instar significantly improved economic traits *viz.*, weight of mature larva, posterior gland, cocoon and cocoon shell **(Nair *et al.*, 2005)**.

Enhance fecundity of honeybees: Ecdysteroids have been proposed as a treatment for the enhancement of fecundity of honey bees in apiculture **(Kholodova, 2001).**

Conclusion

Phytoecdysteroids are plant derived moulting hormones, which are analogues of insect moulting hormones. Phytoecdysteroids mimic insect ecdysone hormone, bind to ecdysone receptors and elicit same responses as insect ecdysone hormone. Phytoecdysteroids induce responses at inappropriate time and stage causing, abnormal development, reduction in fecundity and fertility, reduction in energy reserves and body weight increased cannibalism, death rate and feeding deterrence in non-adapted (sensitive) insects. Its use also improve silk yield in sericulture and enhance fecundity of honey bees in apiculture.

Future thrusts

Need to…

- identify new plant species containing higher amount of phytoecdysteroids
- identify elicitors which induce synthesis of phytoecdysteroids in plants
- breed crop plants with high levels of phytoecdysteroids
- study the safety of phytoecdysteroids to non-target organisms

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