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How do the Sublethal Doses of Insecticides affect Insect Pests and Natural Enemies?

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Introduction

Insecticides remain the most dependable approach for insect-pest control, despite the availability of various innovative novel approaches in integrated pest management. Insecticides have always some effects on the insect pest and other arthropods that might kill the insects or show negative effects without actually being lethal to them. When the insecticides are sprayed in the field, the insecticide concentration reduces from days after initial application, as they degrade due to rainfall, sunlight and wind. Thus insects can be exposed to these sublethal doses and may experience some effects of it. Sublethal effects can be biological, physiological, demographic or behavioural change on the insect population. A sublethal dose/concentration is defined as inducing no apparent mortality in the experimental population. The sublethal effects might be observed as reductions in life span include, development rates, population growth, and changes in behavior, response to pheromonal communication, fertility, fecundity, oviposition, changes in sex ratio, or any deformities. In general, insecticide dose/concentrations under the median lethal (LD_{50}- lethal dose/LC_{50}- lethal concentration) are considered to be sublethal. It is essential to analyse these effects accurately to acquire knowledge about the overall insecticide efficacy for management of insect populations, as well as their impact on non-target organisms, or beneficial arthropods.

Effects on insect biology

These effects may be manifested as reduction in oviposition rate, changes in the developemetal period of different life stages of insect or their longevity. As studied in *Plutella xylostella* L. (Lepidoptera), there is reduction in number of eggs, oviposition period and delayed adult emergence, due to the impact of hexaflumuron. The sublethal effects of cyantraniliprole at LC_{30}, on *Helicoverpa assulta* Guenée (Lepidoptera) showed a decrease in the pupal weight and adult fecundity. In fact there is also sublethal effect of botanicals on insects, in a study it was reported that when *Helicoverpa armigera* Hubner (Lepidoptera) moths ingested neem oil, they showed an increase in pupal period. The essential oils of long pepper and clove on *Spodopetra frugiperda* (J. E. Smith) (Lepidoptera), caused alterations in larval and pupal weight and their period, also decreased their longevity, fecundity and fertility.

Effect on insect physiology

The sublethal effect can be on physiological parameters like, egg fertilisation, ovulation, spermatogenesis, metabolic enzymes, neural conduction, digestion etc. Cyantraniliprole on *Agrotis ipsilon* (Lepidoptera), resulted in reducing lipids, carbohydrates and proteins content, thus affecting larval development and also the activity of esterase enzymes, glutathione S-transferase and oxidases of *Spodoptera exigua* Hübner (Lepidoptera), were reduced. Changes in the embryonic development of *S. frugiperda* were observed after its exposure to sub-lethal concentrations of azadirachtin, lufenuron, and deltamethrin.

The essential oil of Mexican pepper and clove in sublethal concentrations influenced the spermatogenesis and ovarioles histochemistry in *S. frugiperda* and when exposed to sublethal dose of citronella oil the ovarioles showed a reduction in yolk quantity, further caused reproductive failure. It was observed that the essential oil of *Artemisia annua* significantly reduced protein, carbohydrates and lipids levels of *Plodia interpunctella* (Hubner) (Lepidoptera).

Behavioural changes in insects

Sublethal dose/concentrations of insecticides may change the pheromonal communication, behaviour in foraging, finding mate and oviposition site. Some insecticides that affect the endocrine system have the potential to affect reproductive behaviour. Deltamethrin affects the calling behaviour and sex pheromone production in *Ostrinia furnacalis* (Lepidoptera). In addition to negative consequences, insecticides at sub lethal concentration can elicit hormesis or hormoligisis, which is favouring the insect reproductive capacity and can cause outbreak. The sublethal doses of clothianidin on males of *Agrotis ipsilon* (Hufnagel) (Lepidoptera) showed a “biphasic effect”, increased or decreased sex pheromone response depending on the insecticide dosage, however the flight capacity of the

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moths reduced. An increased male response to the sex pheromone (hormesis effect) in *Spodoptera littoralis* (Boisduval) (Lepidoptera) due to sublethal dose of deltamethrin. *Sitophilus zeamais* Motschulsky (Coleoptera) when exposed to essential oils of clove and cinnamon their locomotory behavior, such as time, speed and distance of the walk, got affected.

Changes in insect demography

The sublethal doses greatly influence the growth rate of the initial population as different stages of insects have different susceptibilities to toxicants and this factor should be taken into account while studying for life table bioassay. Sublethal doses may cause a decline in population or can cause havoc by stimulating reproduction. Thus impact on demographic or life table parameters can be like intrinsic rate of increase (*rm*), finite rate of increase (λ), the net reproductive rate (R_0), the mean generation time (T) and the doubling time (TD). Prolonged larval and pupal duration of *Plutella xylostella* (diamondback moth) was revealed from the fertility life table evaluation, after its exposure to sublethal concentrations of chlorantraniliprole. The sublethal effects of spinosad can affect *S. exigua* population dynamics by decreasing its survival, reproduction and delaying its development. *Aphis gossypii* Glover (Hemiptera) exhibit negative instantaneous rate of increase (*ri*) in population when exposed to aqueous extract of neem seeds and castor oil. The study of sub lethal effect on demography of insect-pests can be used as a guide for use of new toxicants and lowering the risk of pest resurgence.

Sublethal effect on beneficial insects

Studies have been done on honey bees and various natural enemies showing sublethal effects after being exposed to insecticides. These may be again physiological or behavioral such as changes in adult longevity, fecundity, neurophysiology, mobility, feeding behaviour etc. Another important impact is on natural enemy's phonological synchrony with the prey or host. Fenoxycarb (Juvenile hormone analog) was reported to prolong the developmental time of all stages except the pupa in case of predator, *Chrysoperla rufilabris*. In some studies it was noticed that the larvae of the predator *Chrysoperla carnea,* unable to produce silk for cocooning due to the effect of Fexonycarb. The adults of reduviid predator *Rhynocoris kumarii*, developed severe abnormalities in the alimentary canal, testis, and ovary when treated with the organophosphorus insecticides- monocrotophos, dimethoate, methyl parathion, at sublethal doses. Changes in orientation were indicated when the parasitoid *Microplitis croceipes* fed with extrafloral nectar of cotton contaminated with sublethal doses of imidacloprid, there was a decrease in the parasitoid's response to odors of the host plant, tested in a wind tunnel. An investigation of the effect of imidacloprid and lufenuron on parasitoid- *Neochrysocharis formosa* Westwood, has resulted in a reduced searching efficiency and oviposition insertions in the host (*Liriomyza trifolii*). Besides these chemical insecticides' sublethal effect, botanicals also have some negative effects on natural enemies. *Coccinella septempunctata* and *Chrysoperla carnea* exposed to azhadirachtin- A treated aphids, showed some morphological deformities. It became difficult for *Trichogramma japonicum* to emerge from rice moth eggs after parasitization, due to the negative effect of biolep (Btk product) and Neemzal (neem-based product). Generally, it's the concentration of the botanical insecticides that acts positively or negatively on natural enemies.

Insect growth regulators (IGRs) which are used for the control of pests, do affect pollinators- the honey bees as well. Some negative physiological effects were noted when *Apis mellifera* and *A. cerana* were treated with Diflubenzuron and showed a reduction in body weight and suppressed hypophrangeal glands. There is a reduction in fecundity observed in the case of *Trichogramma pretiosum*, when exposed to teflubenzuron. It can be realised that none can be escaped from the harmful effects of either synthetic chemical or plant-based chemicals, but conservation measures could be a solution for protecting the beneficial insects from getting affected.

A Solution to protect natural enemies- Conservation

Conservation can be accomplished both by reducing the spraying of insecticides and physical disturbances of the habitat. Restricting the insecticidal spray during susceptible pest life cycle or changing of the spray timing, could be an effective strategy. Mostly natural enemies are active during the hot part of the day, so spraying at the early morning can be a good option to protect both natural enemies and pollinators. A prescribed dose and correct timing of application of the insecticides might prevent the beneficial insects from being affected negatively. Some cultural practices like regular plowing and burning the crop residues may destroy the overwintering sites of natural enemies. Mostly the density and diversity of natural enemies are higher in the organic field than the conventional ones, as there is not much human intervention in organic farming. Some natural enemies favouring crops (clover and alfa alfa) can be grown along with the main crops. Keeping some part of the field free from any insecticidal spray would also be effective in conserving the natural enemies and maintaining the pest and predator/parasitoid population balanced.

Conclusion

Starting from the emergence of larvae from egg to adult longevity and fertility, all stages of the developmental period in an insect life cycle gets affected due to sublethal concentration of insecticides. Both botanicals and chemical pesticides, at sublethal concentrations have negative effects on beneficial insects. Thus assessment of these effects, not only on individuals but also on the insect population is crucial so that the risk of flare back or resurgence or any kind of resistance in insects (pests) can be checked. Furthermore, assessing sublethal effects on natural enemies encourages the development of integrated pest management strategies that combine chemical and biological control in a safer and more effective manner.