Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 03, Issue: 06 (NOV-DEC, 2023)
Available online at http://www.agriarticles.com

Adverse Effects of Pesticides on Natural Enemies

(*Ramesh M Maradi[1], Raghunandana[2] and Prasad Vadigeri[3])
[1]Ph.D. Scholar, Dept. of Agril. Entomology, UAS, Dharwad-05, Karnataka
[2]Ph.D. Scholar, Dept. of Plant Pathology, UAS, Dharwad-05, Karnataka
[3]Technical Assistant, Diploma College, A. C. Vijayapura, Karnataka
*Corresponding Author's email: maradiramesh2011@gmail.com

Recently, plant protection strategy has recommended, minimizing the use of chemical pesticides. Therefore, studying the side effect of insecticides on the natural enemies is highly required to exclude the detrimental effects on the natural enemies. Every crop is infested by various pests; some but not all of them may be controlled by biological means using pathogens, predators, parasitoids and spiders. But to achieve a satisfactory control of complexes of pests, selective pesticides are also indispensable. In fact, they are a prerequisite of Integrated Pest Management.

Introduction

Pesticides released to the environment can directly or indirectly affect target and non-target species in ways that are often contrary to their intended use. Such indirect effects are mediated through direct impacts on other species or the physical environment and depend on ecological mechanisms and species interactions. Typical mechanisms are the release of herbivores from predation and release from competition among species with similar niches. Application of insecticides to agriculture often results in subsequent pest outbreaks due to the elimination of natural enemies. The loss of floristic diversity and food resources that result from herbicide applications can reduce populations of pollinators and natural enemies of crop pests. In aquatic ecosystems, insecticides and fungicides often induce algae blooms as the chemicals reduce grazing by zooplankton and benthic herbivores. Increases in periphyton biomass typically result in the replacement of arthropods with more tolerant species such as snails, worms and tadpoles. Fungicides and systemic insecticides also reduce nutrient recycling by impairing the ability of detritivorous arthropods. Residues of herbicides can reduce the biomass of macrophytes in ponds and wetlands, indirectly affecting the protection and breeding of predatory insects in that environment. The direct impacts of pesticides in the environment are therefore either amplified or compensated by their indirect effects (Stark and Banks, 2003).

Pesticide: A substance used for destroying of pests (insects or other organisms) harmful to cultivated plants or animals or A pesticide is any substance or mixture of substances specifically intended to prevent or repel or destroy or lessen the effect of a pest

Pesticides includes: Herbicide, Insecticide, Nematicide, Rodenticide, Bactericide, Fungicide, Disinfectant, Repellent and Sanitizer…….etc

The factors which influence effect of Pesticides natural enemy populations

- Pesticides types such as contact, stomach poison, systemic, and/or translaminar.
- The application method foliar vs. drench or granular
- The pesticide mode of action.

- The type of natural enemy-parasitoid or predator

Effects of pesticides on natural enemies

We classify pesticide effects on natural enemies into direct and indirect effects.

- Direct effects include short- and long-term impacts on natural enemies due to direct contact with pesticides or pesticide residues.
- Indirect effects are those in which the impact of the pesticide is mediated through the natural enemy's host or prey.
- Indirect effects may be caused by reduction of host or prey populations that serve as food sources for natural enemies, a change in the host or prey distribution (e.g., less clumped), and ingestion of pesticide-contaminated prey or hosts.

Direct Effects

- Short-Term Mortality: The most immediate effect of pesticides on natural enemies is short-term (up to 24 hr after contact) mortality. Short-term mortality has been studied by exposing individuals from a natural-enemy population to one or more levels of pesticide, using both laboratory and field application techniques.
- Developmental stage greatly influences the impact of the pesticide on a natural enemy. Usually adult natural enemies are assayed. However, effects of pesticides on parasitoid immature stages may differ significantly from effects on adults.
- Mode of development can directly influence the impact of pesticides on parasitoids in the field. For example, immature stages of endo-parasitoids can be protected in the bodies of their hosts (Holland *et al*., 2000).
- Many pesticides do not penetrate the chorion of eggs of their lepidopterous hosts. Thus, immatures of some *Trichogramma spp*. can survive applications of pesticides when protected in the host egg.
- Later instars of *Encarsia formosa* Gahan, a parasitoid of the greenhouse whitefly [*Trialeurodes vaporariorum* (West- wood)] are protected within their host's body from direct applications of bioresmethrin.
- Larval stages of ectoparasitoids (e.g., *Diglyphus* spp.) of agromyzid leaf miners may survive insecticide applications due to the protection afforded by the leaf mine.
- Studies do show that sublethal residues of some pesticides are repellent to natural enemies, thereby reducing their searching times on treated surfaces.
- Predators are usually more tolerant of pesticides than are parasitoids. For example, five pyrethroid insecticides (cypermethrin, phenothrin, tralomethrin, fluvalinate, and flucythrinate) were more toxic to the braconid, *Campoletis sonorensis* (Carlson) than to the common green lacewing, *Chrysoperla carnea* Stephens.

Susceptibilities to pesticide residues varied, with LCs for *E. stipulatus* < *A. melinus* < *C. montrouzier* (Hassan, 1982).

Long-Term, Sublethal Effects

- Long-term, sublethal effects to be those that occur more than 24 h after a natural enemy is exposed to a pesticide.
- Sublethal residues may affect those natural enemies that survive pesticide applications, those that emerge as adults from protected situations, or those that disperse into previously treated areas where residues exist.
- Sublethal doses of pesticides can have positive or negative effects on natural enemies. Negative effects are more commonly reported and usually outweigh positive effects. Positive effects include increased fecundity, enhanced parasitoid efficiency, increased mobility, and reduced developmental periods.
- Biological parameters detrimentally affected include daily fecundity, total progeny production, viability, and predation, or parasitism behavior.

- Disruption of normal behavior has been recorded in several natural enemies and includes loss of the ability to recognize hosts, loss of coordination, reduction of predation efficiency, temporary paralysis, termination of feeding and repellent from treated hosts-prey or habitats (Shoeb, 2010).
- Because searching behavior is an important factor in the ability of a natural enemy to regulate its prey or host at low densities, impairment of this behavior could affect the effectiveness of efficient natural enemies.
- Reduced rates of whitefly parasitism and significant changes in the functional response of *Encarsia formosa* when the parasitoid was provided whitefly hosts on *Phaseolus vulgaris* (Auth) leaves treated with sublethal doses of resmethrin

Indirect Effects

- Reduction of Host Populations
- Perhaps the greatest detriment to natural-enemy populations other than acute mortality from pesticides is the reduction in population density of hosts that serve as their food sources.
- Systemic pesticides have been suggested as being a potential solution to the high acute mortality of natural enemies associated with most conventional pesticide applications.
- However, even when systemics are used, problems may occur when pest densities are reduced to such low levels that natural enemy populations are decimated by lack of prey or hosts or they are forced to emigrate .
- This may be particularly serious when natural enemies are highly host specific.

Ingestion of Pesticide-Contaminated Hosts or Prey

Mortality of coccinellid predators such as *Menochilus sexmaculatus* (Fabricius), *Coccinella undecimpunctata* Linnaeus, and *Scymnus syriacus* LeConte has been reported following consumption of aphids poisoned with malathion and demeton. Mortality of *Geocoris punctipes* (Say) nymphs that fed on *Helicoverpa zea* (Bod- die) larvae injected with beta-exotoxin of *Bacillus thuringiensis* Berliner. When adult females of *Bracon hebetor* were exposed to larvae of the almond moth, *Ephestia cautella* (Walker), that had been treated topically with various insecticide dosages, parasitoid mortality increased with dos- age. Mortality or sedation occurred in all individuals of the jumping spider *Phidippus audax* (Hentz) that ate live third-instar *H. zea* larvae previously fed a wheat germ diet containing 40 ppm abamectin. Emerging adult endoparasitoids can suffer mortality from insecticide residues contacted as they bore through contaminated host integument, egg chorion, or scale covers (Vanitha, 2000).

Indirect effects of Pesticides on natural enemies

- Longevity
- Reproduction
- Fecundity and/or fertility
- Development time (egg to adult or specific instars)
- Mobility
- Prey searching efficiency and feeding behavior
- Predation and/or parasitism
- Sex ratio
- Emergence rates
- Prey consumption
- Population growth/reduction
- Repellency
- Orientation behavior
- Prey acceptance (for oviposition by female parasitoids)

Indirect effects on natural enemies associated with different categories of pesticides

Systemic insecticides: Systemic insecticides, when applied as drenches or granules to the soil/growing medium, have been promoted to be relatively non-toxic or minimal direct effects on above ground natural enemies due to lack of any direct exposure. However, this may not be the case as systemic insecticides may exhibit indirect effects on natural enemies via several mechanisms including elimination of prey, contamination of floral parts by the active ingredient, consumption of the active ingredient while ingesting plant fluids, and contamination of prey ingesting either lethal or sub-lethal concentrations of the active ingredient. For example, adults of the parasitoid, *Anagyrus pseudococci* were indirectly affected after feeding on nectar of buckwheat (*Fagopyrum esculentum*) plants that had been treated with a soil application of a systemic insecticide. Foraging ability and longevity of the parasitioid, *Microplitis croceipes* was reduced after feeding on the extra floral nectaries of cotton (*Gossypium hirsutum*) plants that had been treated with systemic insecticides. They may indirectly influence natural enemies if mortality of prey populations is high (>90%) (Cloyd and Bethke, 2011).

Insect growth regulators

Insect growth regulators are compounds that are active directly on the immature stages (larvae or nymphs) of certain insect pests, and there are three distinct categories of insect growth regulators: juvenile hormone mimics, chitin synthesis inhibitors, and ecdysone antagonists. Insect growth regulators have been presumed to be compatible, with minimal indirect affects on natural enemies, and numerous studies have evaluated the indirect effects of insect growth regulators on natural enemies, both parasitoids and predators, under laboratory and field conditions. However, there is distinct variability regarding the indirect effects of insect growth regulators on natural enemies, which is primarily associated with natural enemy type (parasitoid or predator), kind of insect growth regulator, life stage evaluated, and timing of application (spatially and temporally).

Insect growth regulators: The parasitoid species may influence any indirect effects as both *Encarsia pergandiella* and *Encarsia transvena* were not indirectly affected after exposure to pyriproxyfen whereas *Encarsia formosa* exhibited reduced emergence rates, increased development time and decreased parasitization when exposed to different concentrations of pyriproxyfen. Exposure of *Podisus maculiventris* fifth instars to pyriproxyfen did not result any indirect effects on reproduction. Whereas female *Coccophagus lycimnia* failed to produce any progeny. However, exposure to pyriproxyfen delayed development and decreased the parasitization rate of the parasitoid, *Hyposoter didymator*. In addition, pyriproxyfen has been demonstrated to substantially alter the development time of *Chrysoperla rufilabris* immatures. This demonstrates that the parasitoid species, natural enemy type, and developmental life stage may influence the extent of any indirect effects of insect growth regulators (Varma and Singh, 1987).

Kinoprene: Another juvenile hormone mimic insect growth regulator, kinoprene, has been shown to be indirectly harmful to natural enemies by inhibiting adult emergence of the leafminer parasitoid, *Opius dimidiatus* and the aphid parasitoid, *Aphidius nigripes*. Although directly harmful to the parasitoid, *Leptomastix dactylopii*, kinoprene did not indirectly affect percent parasitoid emergence from citrus mealybug (*Planococcus citri*) mummies. Nevertheless, kinoprene may inhibit adult emergence when applied to prey parasitized with larval or pupal stages of certain parasitoids.

Fenoxycarb: Fenoxycarb is a juvenile hormone analog that has shown to be indirectly harmful to certain natural enemies. For example, different concentrations of fenoxycarb delayed the development time from pupae to adult of *Chrysoperla rufilabris* and significantly delayed development of third instar larvae but not first instar larvae. In addition, female reproduction was inhibited when second and third instars were initially exposed to fenoxycarb. The fenoxycarb (at various concentrations) increased duration of larval development of the tachinid parasitoid, *Pseudoperichaeta nigrolineata*. In addition, exposure to fenoxycarb indirectly affected female longevity and fecundity of the predator, *Micromus tasmaniae*.

Cyromazine: Cyromazine is an insect growth regulator that disrupts molting by maffecting cuticle sclerotization through increasing cuticle stiffness in insects. Exposure to cyromazine did not indirectly affect longevity and reproduction of the leafminer parasitoids, *Hemiptarsenus varicornis* and *Diglyphus isaea*.

Diflubenzuron: Another insect growth regulator, diflubenzuron, which is a chitin synthesis inhibitor, has been shown, in general, to have minimal indirect impact on natural enemies both parasitoids and predators under laboratory and field conditions. However, exposure to diflubenzuron decreased female longevity and reduced the parasitization rate of the endoparasitoid, *Hyposoter didymator* and reproduction of the parasitoid, *Eulophus pennicornis*. It was reported by that *Micromus tasmaniae*, when exposed to diflubenzuron, resulted in indirect affects on reproduction, sex ratio (female bias), and longevity. In contrast, diflubenzuron exhibited no indirect effects on the reproduction of *Podisus maculiventris* adults. Additionally, diflubenzuron displayed minimal indirect effects on the parasitoid, *Macrocentrus ancylivorus*. Similar to other insect growth regulators, any indirect effects of diflubenzuron are likely associated with the natural enemy type, timing of application (spatially and temporally), and exposure time (Hamada, 1992).

Buprofezin: A chitin synthesis inhibitor has been shown to sterilize certain natural enemies, and reduce the number of progeny produced per female and alter sex ratios. In addition, feeding on buprofezin-treated sweet potato whitefly (*B. tabaci*) eggs resulted in a decrease in female fertility and fecundity, and sterilized the males of the predatory coccinellid, *Delphastus catalinae* indicating no compatibility with this IGR. However, the higher rates (500 and 1,000 mg active ingredient per liter) when applied to first instars did prolong overall development to adult whereas second and third instars and pupae were not affected. This indicates that the specific life stage exposed to insect growth regulators may vary in susceptibility with early instars tending to be more susceptible than later instars and adults to chitin synthesis inhibiting IGR. Buprofezin, when applied at three different concentrations (100, 500, and 1,000 mg active ingredient per liter), did not indirectly affect egg viability and subsequent development of *C. rufilabris*. However, buprofezin did not negatively affect development (nymph to adult) of the predatory bug, *Orius tristicolor* or inhibit female reproduction of the predatory mite, *P. persimilis*. Azadirachtin: is an ecdysone antagonist which may exhibit variability regarding any indirect effects on natural enemies, for example, that azadirachtin inhibits oviposition of the green lacewing, *C. carnea* and indirectly affected both fertility and fecundity. In addition, exposure to azadirachtin decreased longevity and predation rates, and inhibited prey finding. Furthermore, the sex ratio was male biased . Three different formulations (0.3%, 4.5%, and 1.6%) of azadirachtin were reported to indirectly affect the fecundity of *Macrolophus caliginosus* females (Zaki *et al*., 1999).

Microbials:

Although entomopathogenic fungi and bacteria (*Bacillus thuringiensis*) are, in general, not indirectly harmful to natural enemies, this may vary depending on concentration, natural enemy type, life stage exposed, timing of application (spatially and temporally), and environmental conditions (temperature and relative humidity). The fact that indirect effects may not be immediately associated with either the entomopathogenic fungi or bacteria, but may be due to altering the availability of the food source or killing prey before parasitoid immatures have completed development. Natural enemies may ingest fungal conidia when grooming (cleaning themselves) or when feeding on contaminated hosts; however, the extent of any indirect effects primarily depends on the concentration of spores present. In addition, entomopathogenic fungi may indirectly affect certain natural enemies when feeding on prey that have been sprayed (contaminated prey). For example, larvae of the mealybug destroyer, *Cryptolaemus montrouzieri* were killed (50% mortality) after consuming mealybugs that had been sprayed with *Beauveria bassiana*. Moreover, exposure to *B. bassiana* reduced the fecundity of *Neoseiulus californicus* females whereas the fungus *Cephalosporium lecanii* exhibited no indirect effects on longevity of the leafminer parasitoid, *Diglyphus begini*. In another study, conducted under laboratory conditions. The exposure to *Metarhizium anisopliae* had no indirect effect on prey consumption (fungus gnat larvae) of rove beetle, *Atheta coriaria* adults.

In addition, ovipositing females may avoid prey that are infected by entomopathogenic fungi. The microorganism spinosad has been demonstrated to be indirectly harmful to a variety of predatory insects including the green lacewing, *C. carnea*; ladybird beetle, *Hippodamia convergens*; minute pirate bug, *Orius laevigatus*; big-eyed bug, *Geocoris punctipes*; and the damsel bug, *Nabis sp*. For example, it was determined that exposure to spinosad extended development time from first instar to adult and decreased fertility of *Harmonia axyridis* females. Nevertheless, exposure to spinosad did not inhibit foraging behavior and reproduction of *Phytoseiulus persimilis* females. However, exposure to spinosad did not indirectly affect the sex ratio of the parasitoids, *Aphytis melinus* and *Leptomastix dactylopii*, and there was no significant effect on reproduction and longevity of *Leptomastix dactylopii* females (Cloyd, 2006).

Miticides

Miticides, similar to other pesticides, may demonstrate variability in regards to any indirect effects on natural enemies depending on the type of miticide and predatory mite species. The miticide fenpyroximate did not negatively affect prey consumption of *Neoseiulus* (*Amblyseius*) *womersleyi* on twospotted spider mite (*Tetranychus urticae*) eggs compared to the miticide pyridaben. However, both miticides indirectly affected reproduction of *N. womersleyi* and *P. persimilis* females. Egg viability of *P. persimilis* was not affected by either miticide but was for *N. womersleyi*. Furthermore, the population growth, based on reproduction and egg viability, of *N. womersleyi* was indirectly affected more so by pyridaben than fenpyroximate. Overall, fenpyroximate appeared to be more compatible with both predatory mite species. Similarly, found that exposure to different concentrations of fenpyroximate did not indirectly affect female reproduction, immature development time, fecundity, and the sex ratio of progeny associated with *N. womersleyi*. The miticides bifenazate, etoxazole, acequinocyl, chlorfenapyr, and fenbutatin oxide were shown to exhibit no indirect effects on the reproduction of *P. persimilis* females under laboratory conditions, and adult females that fed upon prey treated with the miticides were not indirectly affected based on sex ratio of progeny, prey consumption, and female reproduction. This indicates that these miticides are in fact compatible with this predatory mite (Hoy and Cave, 1985).

Fungicides

Although, in general, fungicides may be considered less harmful to natural enemies than insecticides and miticide, it is still critical to determine any indirect effects and thus compatibility with natural enemies since fungicides are extensively used in agricultural and horticultural production systems and as such it is justifiable to evaluate their indirect effects on natural enemies. It may be that the fungicide type will determine compatibility with natural enemies as 'older' fungicides could be more indirectly harmful to natural enemies than 'newer' fungicides, which may be associated with the mode of action or any metabolites. Although similar to other pesticides, this may depend on the natural enemy type and species, timing of application (spatially and temporally), and life stage exposed. For example, mancozeb was shown to negatively affect fecundity and reproduction of the predatory mites, *Amblyseius andersoni*, *Galendromus occidentalis* and *Euseius victoriensis* under laboratory and field conditions and benomyl indirectly inhibited reproduction of female *Amblyseius* *fallacis* and *Galendromus occidentalis*. However, mancozeb did not indirectly affect longevity or reproduction of two leafminer parasitoids, *Hemiptarsenus varicornis* and *Diglyphus isaea*. It was determined that the 'newer' fungicides, azoxystrobin and fosetyl-aluminum did not inhibit prey consumption (fungus gnat larvae) of rove beetle, *A. coriaria* adults under laboratory conditions.

Conclusion

The compatibility of natural enemies with pesticides depends on a range of factors including class of pesticide applied, natural enemy type (parasitoid or predator), natural enemy species, pesticide formulation, concentration in which natural enemies are exposed to, exposure time, timing of application (spatially and temporally), and developmental life stage (early *vs*. later instars) exposed to pesticide. As such, there are three primary means by which natural enemies may be integrated with pesticides including pesticide selection (using non-nerve toxin or "selective" pesticides), spatial separation (applying pesticides to localized areas of infestation) of natural enemies and pesticides, and temporal discontinuity (applying pesticides when natural enemies are absent or when tolerable life stages are present) between natural enemies and pesticides. The compatibility of natural enemies with pesticides is important if both these management strategies are to be integrated into programs designed to regulate arthropod pest populations and minimize plant damage.

References

1. Cloyd, R. A. (2006). Compatibility of insecticides with natural enemies to control pests of greenhouses and conservatories. *Journal of Entomological Science*, 4(1): 18-29.
2. Cloyd, R. A. and Bethke, J. A. (2011). Impact of neonicotinoid insecticides on natural enemies in greenhouse and interiorscape environments. *Pest Management Science*, 7: 6-7.
3. Hamada, R. (1992). Egg parasitoids of common cutworm, *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae). *Japanese Journal of Applied Entomology and Zoology*, 36: 258-259.
4. Hassan, N. A. (1982). Mass production and utilization of Trichogramma. 3 results of some research projects related to the practical use in the Federal Republic of Germany. Les Trichogramma. Colleagues INRA, 9:213-218.
5. Holland, J. M., Winder, L. and Perry, J. N. (2000). The impact of dimethoate on the spatial distribution of beneficial arthropods in winter wheat. Annals of Applied Biology, 136:93-105.
6. Hoy, M. A. and Cave F. E. (1985). Laboratory evaluation of avermectin as a selective acaricide for use with *Metaseiulus occidentalis* (Nesbitt) (Acarina: Phytoseiidae). *Applied Entomology and Zoology*, 10:39-41.
7. Shoeb, M. A. (2010). Effect of some insecticides on the immature stages of the egg parasitoid *Trichogramma evanescens*. *Egypt Academy of Journal biological Sciences*, 3: 31- 38.
8. Stark, J. D. and Banks, J. E. (2003). Population-level effects of pesticides and other toxicants on arthropods. *Annual Review of Entomology*, 6(4): 48-50.
9. Vanitha, K. (2000). Studies of predatory spider of rice pests. *M.Sc. Thesis*. TNAU, Coimbatore, India.
10. Varma, G. C. and Singh, P. P. (1987). Effect of insecticides on the emergence of *Trichogramma brasiliensis* (Hymenoptera: Trichogrammatidae) from parasitized host eggs. *Entomophaga*, 32: 443-448.
11. Zaki, F. N., Farag, N. A. and Abdel-Aziz, S. E. (1999). Evaluation of tolerance in *Chrysoperla carnea* to successive insecticidal treatments. *Journal of Applied Entomology*, 123: 299-301.