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Pesticide-Organism Interactions[1]

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This guide addresses the various responses of living organisms to pesticides.

Both the beneficial and harmful effects of pesticides are determined by pesticide-organism interactions or how pesticides and organisms react to each other. To do its job, a pesticide must: 1) penetrate the organism, 2) move or be transported to the site of action, and 3) there disrupt or alter the vital function. The manner in which the pesticide affects the vital function is called its *mode of action*. Penetration, transport, and mode of action involve pesticide-organism interactions. Pesticide-organism interactions also are involved in the metabolism, accumulation, and elimination of pesticides by the organism as well as in biodegradation and biological magnification.

Selectivity and Resistance

Selectivity (the ability of a pesticide to kill or otherwise alter one organism and not another) and the development of pesticide resistance are often caused by differences in pesticide-organism interactions. Resistance is the inherent ability of a pest to sustain less damage from pesticide application than other individuals of that species under comparable environmental conditions. An example of resistance to pesticides worldwide is in insects and mites. In the early 1990s, more than 500 species of arthropods were known to be resistant to insecticides. Pesticide resistance is not limited to arthropods; there are at least 200 species of fungi, over 200 species of weeds, and several species of nematodes and rodents also resistant to one or more pesticides. Resistance often develops in pest populations that have been repeatedly treated with a single pesticide. Development of resistance in pest populations may sometimes be averted or delayed by avoiding the use of persistent pesticides, reducing the number of treatments and alternating pesticide modes of action.

Penetration

The speed and extent of penetration depends on the permeability of the organism to the specific pesticide. This permeability differs significantly among plants and insects and even among different tissues of the same organism. Among animals, tissues of the respiratory and digestive system are usually much more permeable than the skin. With plants, hardened growth and bark generally provide a more effective barrier than new and succulent growth. The

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Use pesticides safely. Read and follow directions on the manufacturer's label.

ability of a pesticide to penetrate an organism depends on its chemical nature and the formulation. Penetration may be increased under certain conditions, such as high temperature and application of emulsifiable concentrates, which often contain petroleum solvents as inert ingredients.

Transport

The movement of a pesticide from the place where it entered an organism to its site of action involves the mobility of the pesticide molecule and the efficiency of the transporting mechanism of the plant or animal, i.e., how quickly the pesticide moves through the plant or animals system. Systemic herbicides must move through the plant to areas of interaction. Other herbicides are non-mobile in the plant and only affect the tissue with which they come in direct contact.

Mode of action

A pesticide performs its main function only after it reaches its site of action within an organism. These sites are usually the protoplasm of living cells and often particular kinds of cells. For example, the cells affected by organophosphate insecticides are the nerve cells. The herbicide atrazine affects photosynthesis in the chloroplasts of susceptible plant cells.

Pesticides kill or otherwise alter an organism by disrupting or interfering with some vital physiological function. This is known as the pesticides mode of action. The mode of action of orgranophosphate insecticides (e.g., methyl parathion and malathion) is the inhibition of the breakdown of acetylcholine by cholinesterase, an enzyme that is essential in regulating the proper functioning of the nervous system. When acetylcholine accumulates, muscles and glands become overactive because of excessive stimulation of the nerve cells. Some herbicides, such as 2,4-D, act as plant growth regulators, speeding up or slowing down cell growth and reproduction; other herbicides may target vital plant functions or specific enzymes. For example, one major class of herbicides, the acetolactate synthase inhibitors, blocks the synthesis of an enzyme which is critical for the production of several amino acids within the plant. Fungicides may act as inhibitors of spore germination and fungal growth.

Metabolism

Metabolism is the process by which a pesticide, or other chemical, is changed into one or more different chemicals within a living organism. The metabolic product, or metabolite, may be either more toxic or less toxic than the original pesticide ingredient. Aldicarb, the active ingredient in Temik®, has the metabolites sulfone and sulfoxide, which are much more toxic than the parent molecule. Some pesticides are effective only after they have been metabolized to a lethal compound by an organism. For example, 2,4-DB is changed rapidly to 2,4-D by broadleaf plants other than legumes. Actually, 2,4-DB is relatively harmless to the plant in itself. Enzymes of susceptible broadleaf plants alter the compound, forming the toxic 2,4-D. Given enough time, an organism may be able to metabolize certain pesticides to their nontoxic metabolites. Survival may depend on whether or not the organism can metabolize the pesticide into nontoxic metabolites before the toxic activity is complete or irreversible.

Accumulation, elimination, and detoxification

Pesticide chemicals and their metabolites may be stored or accumulated within an organism or be eliminated as waste. Metabolism can be induced based on exposure.

Because pesticide residues may accumulate within organisms, special precautions in harvest or slaughter must be observed with the treated commodities. Grazing, harvest, and slaughter restrictions provide the necessary time for metabolites to be detoxified or eliminated before safe consumption of the treated product is allowed.

Biological magnification

Biological magnification is the tendency for certain pesticides to progressively become more concentrated in each type of organism when moving from the bottom to the top organism within a food chain. Perhaps the most familiar example of reproductive effects of pesticides on nontarget organisms is the eggshell thinning in birds that was caused by certain organochlorine insecticides such as DDT. This eggshell thinning may have been initiated by a chain of events beginning when invertebrates that consumed plants with DDT residues were, in turn, eaten by rodents, reptiles, amphibians, fish, and insectivores, further concentrating the residues in their fat tissues. These predators were eaten by top predators in the food chain that then received yet higher insecticide concentrations. The majority of organochlorine uses have had their registrations banned in the United States for a number of years, and such biological magnification problems have reversed themselves. Top predators are again increasing in number. During the 1990s, the bald eagle was removed from the endangered species list because the reproductive capacity of the population has been increasing. Thus, awareness of such pesticide-organism interactions is important when working with certain pesticides.

Additional Information

Valles, S. M. and P. G. Koehler. 1997. Insecticides Used in the Urban Environment: Mode of Action. UF/IFAS Fact Sheet ENY-282. http://edis.ifas.ufl.edu/IN077. Visited June 6, 2005.