HOW LONG DO INSECTICIDE RESIDUES PERSIST?

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A question that I frequently get asked is "How long do insecticides last after spraying?" Usually this question relates to the insecticidal effectiveness of the spray. But with some growers experiencing abnormally high acephate residues in 2003, the question is equally relevant to residues at the time harvest in relation to federally-allowable limits. The question is not an easy one to answer, as a diversity of factors impact insecticide persistence. Further, in many cases, there has been little research on specific pesticides against specific pests on specific crops. Once the Environmental Protection Agency (EPA) determines what the allowable residues will be on a crop at harvest, chemical companies must then do field trials to determine how long residues last after application. But much of this information is held by the companies and never published in accessible locations. Further, for pests of minor crops such as cranberry, there has been relatively little research done on the effective life of pesticides after spraying, or the factors that lengthen or shorten the period of effectiveness.

Insecticides begin to break down as soon as they are mixed in the spray tank. Indeed, many products start to break down while still in the original container, and most products have an acknowledged shelf life. Once mixed and applied, factors that influence rate of breakdown include

- the chemistry of the insecticide,
- chemical and physical properties of spray additives,
- chemistry (pH, hardness) of the spray water,
- a multitude of environmental factors (temperature, humidity, rainfall),
- factors relating to the plant (surface chemistry, waxiness, etc.).

All of these factors can influence (1) the insecticidal effectiveness of a product , (2) its fate and persistence in the environment, and (3) the amount of residues left in or on the berries at harvest.

Defining some terms. The following terms relate to pesticide residues.

Residue. Any quantity of the originally applied pesticide chemical. This can refer to residues in or on the plant, or in the environment, such as soil residues.

Residual effectiveness. The period of time the the applied material remains as an effective insecticide.

Half-life. The amount of time it takes for ½ of the original material to be broken down or removed. For each additional half-life period, 50% of the remainder will be lost.

Breakdown product. Insecticides disappear in a variety of ways. They may be washed off and end up in the soil or water. They may evaporate. Or they may decompose. Decomposition can be caused by light (photodecomposition), chemical reactions, or other factors. When the molecules break down, smaller molecules of various types remain; these are called breakdown products. These in turn can further decompose into yet additional breakdown products. Breakdown products may be either more or less toxic (e.g. to mammals) than the original insecticide. For example, a breakdown product of acephate is methamidophos, which is itself manufactured and sold as an insecticide. Methamidophos is about 50 times more toxic to mammals (by oral exposure) than is acephate.

Tolerance. This is the level of a pesticide that is allowable in a commodity that is in a position to be purchased and used by a consumer. Tolerances are established by EPA. Based on rates of decomposition, the tolerances dictate the amount of product that can be used on the crop (rate of application; number of sprays) and the Preharvest Interval (days between last application and harvest).

Insecticide residues: a historical review. Until recently, in the historical development of insecticides, most could be grouped into six major categories based upon either their derivation or their chemistry. Each group has somewhat different residue characteristics. I have gleaned the following information from a variety of sources; in some cases the information is a bit ambiguous.

- Inorganic (elemental) insecticides are those that are based on the elements, such as sulfur, lead, and arsenate. As elements, they can not be further broken down and therefore have a long persistence. However, they can be combined with other chemicals; such molecules may have different toxicity characteristics from the elements themselves.
- Botanical insecticides are those that are derived directly from plants, such as pyrethrum and rotenone. These have a relatively short persistence on plants and in water and soil. Pyrethrins, the insecticidal molecules in pyrethrum, are rapidly decomposed by water, light, and mildly acidic or alkaline pH. Rotenone has a half-life of only 1-3 days, and in the heat of summer is nearly totally lost within 2-3 days.
- Organochlorine insecticides include such materials as DDT, chlordane, and aldrin, which have long since been discontinued because of their very high persistence in soil and water. The half-life of DDT is 2-15 years; for chlordane 4 years.
- The organophosphate (OP) and carbamate insecticide groups are nerve toxins. Though chemically different, they have similar properties. Most of our older cranberry insecticides are organophosphates, including phosmet, acephate, chlorpyrifos, and azinphosmethyl. The insecticide of choice in cranberry many years ago was parathion, an OP that is no longer available. Carbaryl is a carbamate. The following are examples of these two groups. Parathion is relatively short-lived; the half-life on foliage is 1 day to 2 weeks; breakdown is slower in soil. Chlorpyrifos has a soil half-life of 11-140 days; persistence increases in more acidic soils; "residues" (unspecified levels) occur on plant surfaces for 10-14 days after application. Carbaryl has a soil half-life of 7-28 days; plant surface residues (unspecified levels) usually last less than 14 days.
- Microbial insecticides are those which include living microorganisms such as bacteria, fungi, or viruses. These microbes are usually very susceptible to ultraviolet light and die quite rapidly when exposed to sunlight; persistence is longer if protected in the soil. *Bacillus thuringiensis* (Bt) is the most commonly used microbial insecticide in cranberry. In one study it was found to have a soil

half-life of 4 months, but this included reproduction in the dead cadavers of its host insects. The half-life on foliage exposed to sunlight is about 4 hours.

Reside impacts: insecticidal effectiveness. The following table contains data of cranberry insecticides derived from a variety of sources. The fact that some of the data are conflicting reflects on the complexity of variables that affect persistence of residues. Also, note that the data are presented in different ways, such as "half-life" vs. "residual" vs. "effectiveness." Also note that none of the data are derived from cranberry; the limited data available are largely from major crops such as cotton and soybean; results on cranberry might be quite different.

Product	**Residual on Foliage**
acephate (Orthene™)	1-15 day half-life.
azinphosmethyl (Guthion™)	3-5 day half-life. 2 weeks of effectiveness.
Bt	4 hour half-life.
carbaryl (Sevin™)	Less than 14 day residual.
chlorpyrifos (Lorsban™)	10-14 day residual.
diazinon	2-14 day half-life.
phosmet (Imidan™)	No data located.
spinosad (SpinTor™)	No data located.
tebufenozide (Confirm™)	No data located.

A closer look at the above information for azinphosmethyl is quite revealing. It has a relatively short half-life on foliage (3-5 days) but it has 2 weeks of effectiveness. This indicates that the recommended rates are sufficiently high to allow for longer residual effectiveness.

The following factors generally **decrease** the residual effectiveness of an insecticide (but note that the amount of decrease can vary with product and other factors):

- lower application rates,
- high pH (greater alkalinity) of spray water,
- high pH of overhead irrigation water,
- amount of irrigation or rainfall,
- amount of sunlight,
- high temperatures, low humidity, wind.

Residue impacts: fate in the environment. Generally, pesticide contamination of the environment is viewed unfavorably and we do everything that we can to avoid such problems. In fact, it is impossible to totally avoid insecticide residues on non-target plants, in the soil, or in water. The following factors tend to **increase** environmental persistence:

- more product used: more applications and/or higher rates,
- neutral to acidic spray water and irrigation water,
- how soluble the material is in water,
- how much adhesion it has to soil particles and organic matter,
- amount and intensity of irrigation and rainfall,
- favorable soil and water chemistry,
- lack of microorganisms that decompose pesticide molecules,
- low soil temperature and moisture.

Residue impacts: residues in the crop. By law, pesticide residues on the consumable crop can not exceed federal tolerances. To avoid illegal residues, the insecticide label includes directions on the allowable rates of use, the possible frequency of application, the number of applications, the total amount that can be applied during one cropping cycle, and the minimum time that must be observed between the last application and harvest. Many of the same factors that often increase environmental persistence also impact insecticide decomposition in or on the fruit. Some of these factors include

- more product used: more applications and/or higher rates,
- closeness to harvest,
- adsorption to the fruit surface (a property of the material and adjuvants),
- amount of weathering and irrigation,
- low temperatures and/or high humidity.

Some summary thoughts. Very little data on residues exist in accessible literature; most is proprietary information of the chemical companies. Information that is available is mostly from major crops; I could find nothing specific to cranberry. Even less information is available on the newer chemicals becoming registered, from newer insecticide classes. However, many of the newer products are more selective, with fewer non-target effects; many have a very low level of toxicity to humans. Therefore, these products may have very acceptable periods of residual effectiveness with fewer concerns of having unacceptable residues in the crop.

Web sources for pesticide information. The following websites contain useful pesticide information:

- Extension Toxicology Network: http://ace.orst.edu/info/extoxnet
- CDMS Ag Chem Information Services: http://www.cdms.net/manuf/manuf.asp
- US EPA: http://www.epa.gov/ebtpages/pesticides/html