Managing Pesticide Resistance Development

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Pesticide resistance is the selection of individuals in a population to become better able to survive exposure to a pesticide after the population has been exposed repeatedly to that pesticide over a period of time. It results from the phenomenon commonly known as "survival of the fittest." Some species are notorious for the ability to develop resistance (mites, thrips), whereas others appear to do so more slowly. Resistance occurs in all agricultural pest groups – insects, mites, fungi, bacteria, weeds, and nematodes. Proper management of agrochemicals to prevent the development of resistance is extremely important because the development and registration process for new chemicals is slow and expensive. If existing chemicals become ineffective due to resistance development, alternatives may not be available, may be very expensive, and/or there may be quite a delay before their registration occurs. This article focuses on pesticide resistance, but the principles discussed are applicable to other agrochemicals, such as fungicides and herbicides.

How does pesticide resistance develop?

Pesticides are rarely 100 percent effective. A few individuals will survive an application – due to natural tolerance, lack of exposure due to poor coverage or their ability to hide and limit their exposure – and reproduce. These survivors possess traits that may be behavioral, genetic or biochemical, which allow them to tolerate the effects of a pesticide. When these survivors reproduce, they pass on these "resistance traits" to some of their offspring. This results in a larger proportion of the individuals in subsequent generations being less susceptible to the pesticide. This is shown in the accompanying illustration, which shows how a population can shift from being composed predominantly of susceptible individuals (represented as yellow in the diagram on page 35) to being composed of resistant individuals (represented as red) following repeated applications of the same pesticide.

How can pesticide resistance be managed?

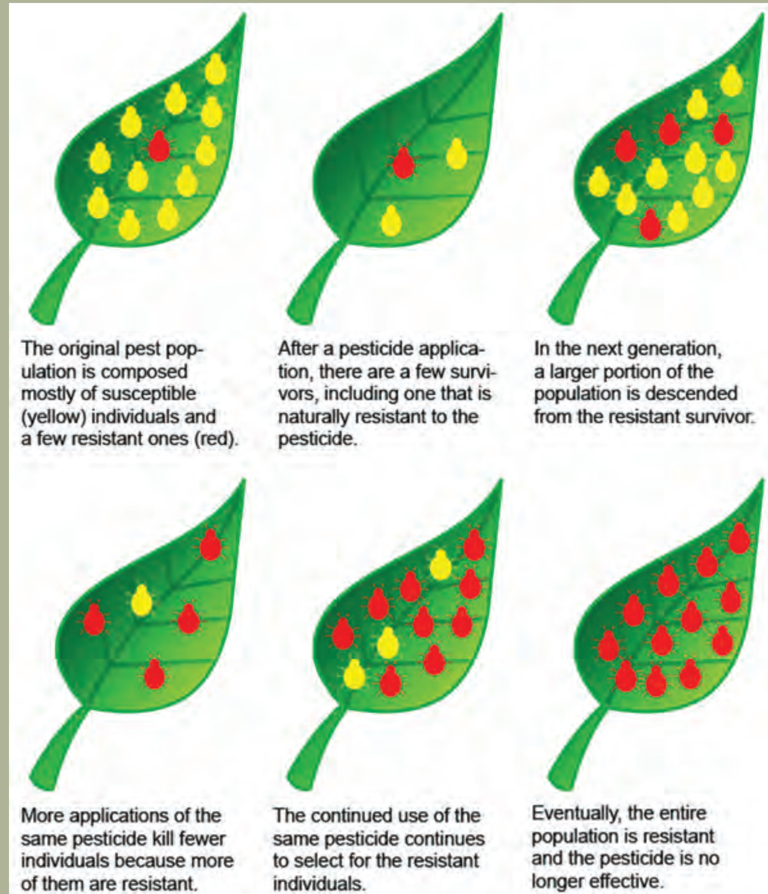
The basic principle of managing pesticide resistance is to never unnecessarily expose a pest to a pesticide. To achieve this, a few simple rules should be followed which are articulated below:

Never rely on a single pesticide mode-of-action

Pesticides are grouped based on how they act on a pest, which is known as the chemical's mode-of-action. An international group known as the Insecticide Resistance Action Committee (IRAC) is responsible for classifying pesticides. Currently, IRAC groups pesticides into 27 different groups, which are indicated by a number (1 through 28 – 26 and 27 are currently not in use) or the letters "un" for chemicals of unknown mode-of-action. Some groups contain subgroups, which are indicated by a letter following the group number.

For example, group 1 (chemicals with nerve action) has two subgroups, 1A and 1B, which represent carbamates and organophosphates, respectively. It is very important to understand that, although these subgroups represent distinct chemical classes, they have the ***same*** mode-of-action. Therefore, when selecting chemicals to rotate mode-of-action, you must choose between different groups, not subgroups.

When a chemical of a given mode-of-action is applied to a pest population, there will be a small portion of the population that naturally has some resistance to that mode-of-action. However, it is very unlikely that they are resistant to a different mode-of-action. Thus, if the next pesticide application uses a different mode-of-action, these individuals can be killed. By using as many different modes-of-action as possible, the likelihood of resistant individuals surviving is reduced and the pest population does not develop resistance.



Integrate cultural and biological control with pesticide use; monitor and treat only when pest pressure justifies treatment

One of the cornerstones of managing pesticide resistance is to reduce pest exposure to pesticides. An excellent way to do this is by using cultural practices and biological control strategies in your pest control program.

Cultural practices commonly include things like weed management, grove sanitation by removing or chipping pruning debris and fallen fruit, and controlling alternative host plants. Weeds can serve as alternative hosts for some pests, but often act as a refuge for pests to escape pesticide applications made to the tree canopy. Once the pesticide residue has diminished, the pests can re-infest the canopy. Grove sanitation is very important for certain pests that live in the wood or fruit of the tree, including the new Polyphagous Shot Hole Borer. Pests like the shot hole borer or seed weevils (not currently present in California) can easily re-infest trees by emerging from pruned branches or fallen fruit that lay on the grove floor. By physically removing debris from the grove, or breaking it down with a chipper or mower, these types of pests can be better controlled. Controlling alternative host plants in and around the grove is another non-pesticide technique for helping to control pests. This technique, like sanitation, is beneficial for pests like the shot hole borer, which can infest numerous species other than avocado. Having alternative host species in and around your grove can act as a freeway for pests to move in. However, removing the alternative hosts can slow a pest's spread, and limit its population growth.

Biological control, or biocontrol, is a strategy for controlling pests using other living organisms, including predators, parasitoids and pathogens. Biocontrol often requires active human management to import, augment or conserve the biocontrol agents. For many insect and mite pests, biocontrol relies upon the establishment of other insects or mites (either native or imported) that feed on the pest, frequently its immature stages (e.g., the predatory mite *Galendromus helveolus* preys upon persea mite). However, many biocontrol agents parasitize pests by laying their eggs in or on the pest, and the biocontrol young then feed on the pest (e.g., the parasitic wasp *Thripobius semiluteus* lays eggs in the larvae of greenhouse thrips). A third class of biocontrol agents are pathogens of the insect pest. In managed biocontrol programs, this class is probably best represented by fungi that are insect pathogens, also known as entomopathogenic fungi.

A cornerstone of pesticide resistance management is to use pesticides only when they are needed. That is, monitor pest populations and do not spray on a calendar basis. Different pest control advisors have different methods of monitoring and different treatment thresholds, but the key point is to reserve chemical use for when it is needed. This not only saves money, but also reduces selection for pesticide resistance.

Use pesticides at label recommended rates and strive for thorough coverage

Even though minimizing a pest's exposure to pesticides is key to resistance management, when pesticides are needed it is very important to use the correct rate and application method. If pesticide rates lower than those recommended on the label are used, a large portion of the pest population will be exposed to sub-lethal doses. This exposure to sub-lethal doses can hasten the development of resistance in a manner analogous to humans receiving allergy shots where repeated exposure to low doses of an allergen leads to desensitization, or resistance in the case of insects and pesticides.

Likewise, if the correct pesticide rates are used, but coverage is poor, then a portion of the population is exposed to sub-lethal doses, or maybe even no pesticide. This can result in resistance development from sub-lethal exposure, and rapid rebound of the pest population, which will result in more use of pesticides.

Never use tank mixes of pesticides with the same mode-of-action

Tank mixes of pesticides have become increasingly common in agriculture. They allow for efficient application of multiple products at the same time. It is very common for tank mixes to include a pesticide and a fungicide, or a contact insecticide and a systemic insecticide for quick knock-down and long-term control of a pest. However, it is very important that two pesticides with the same mode-of-action are never tank mixed and applied together. This would be equivalent to simply increasing the rate of one of the pesticides to twice the label rate, for example. This "super dose" of pesticide will likely be very effective against a large portion of the pest population, but, as mentioned earlier, pesticides are rarely 100 percent effective. Therefore, the individuals that do survive this super dose will be the most resistant in the population, and resistance will be selected for that much faster.

Minimize use of persistent pesticides with long residual activity

Many of the pesticides available today are relatively "soft" compared to those used in the past. That is, they quickly break down after application to non-toxic compounds. This is considered a good thing from a pesticide resistance standpoint since it means that the pesticides will not be in the environment for an extended period, slowly degrading, and exposing pests to sub-lethal doses, which we know can lead to resistance development. An example of a pesticide with a relatively long residual that is still used today is Danitol, which can remain effective, depending on the pest, for several weeks. These pesticides should be used judiciously.

It is important to note that pesticides with long residuals are distinct from systemic insecticides that provide long-term insect control by being "stored" within the plant. However, systemic pesticides are not immune from resistance development, and should also be rotated according to their mode-of-action.

If control with a pesticide fails, never re-treat with the same pesticide or one with the same mode-of-action

If you make a pesticide application and it fails to reduce the pest population to an acceptable level, you should ***never*** re-treat with the same mode-of-action. Even if you are fairly certain that the applicator mixed the pesticide incorrectly or there was an issue with coverage, it is always best to assume that the failure was due to some level of resistance development – even if this is an incorrect assumption. By making this assumption and following the rules of resistance management, you will make a follow-up treatment with a pesticide of a different mode-of-action. If there are the beginnings of resistance in your pest population, the new mode-of-action will kill the pests with the resistance to the first mode-of-action. If the failure of the first application was due to mixing or coverage issues, hopefully these issues will not occur a second time.

The bottom line on most of the above principles is to minimize the frequency with which pests are exposed to one class of pesticides – use all of the above methods to do this in concert. Pesticide resistance development is a critical issue to today's agriculture industry that we all must be vigilant about. Pesticide research and development is a slow and expensive process. New pesticide chemistries do not come on the market very often, and when they do they are expensive. If the effective products we currently have available are lost due to resistance development it could be years before new alternatives are available. Continuously using one pesticide, whether it's because it is the cheapest or the easiest to apply, will only result in the eventual loss of that product, forcing the use of newer, more expensive products. And the loss of one product puts greater pressure for resistance development on the remaining products since there are fewer products left to rotate among.

Good pesticide stewardship is the responsibility of all of us, and it will help to ensure that we can continue to grow the crops we enjoy, and produce safe, quality products for consumers.