and to enhance penetration or translocation.

Selecting and using adjuvants requires the same attention to detail that is given to selecting and using pesticides. Read the adjuvant and pesticide labels to see if they are suitable for each other, and for the spraying conditions and other particulars of your situation. Use a jar test to see if the materials are physically compatible. Follow adjuvant label rates. As with pesticides, more is not better and can cause serious problems. If possible, evaluate product performance. For example, if a spreader is used, check spray deposit on foliage. With too much spreading, the spray may just run off the leaves in a straight line.

Adjuvants can be valuable tools. However, many pesticide formulations already include necessary adjuvants, and adding additional materials may cause plant injury (especially with EC formulations), reduce pesticide effect, or provide insufficient benefit to justify the extra cost.

ALTERNATE ROW SPRAYING

By traveling down only every other row when spraying, the amount of time and pesticide used per acre can be cut in half for a given application. Alternate row spraying requires a sprayer that has adequate air volume and velocity to provide at least light spray coverage on at least 90% the tree with each one-side spray. The sprayer should push some mist 10 to 15 feet beyond the tree. For the next spray, the sprayer is driven down the rows that were not traveled during the previous spray.

If alternate row spray coverage is adequate, applications do not have to be made exactly twice as often as an every-row spray. In other cases, applications are made twice as often, but the amount of pesticide used each time is less than half of what would be used for an every-row spray, because of the short interval between renewed pesticide coverage. As a result, pesticide usage over the season can be significantly reduced.

Alternate row spraying may increase the survival of beneficial species, and may reduce the chances of pests developing pesticide resistance. In emergency situations it allows for twice as many blocks to receive some protection in a given time period, as opposed to getting half of the blocks treated with full block application while the other blocks receive no protection at all.

Mention of alternate row spraying in this publication is not meant to be an endorsement. The first spray of the season should achieve full block coverage. Contact the your state Extension for more information.

BORDER ROW SPRAYS

Border row sprays have been used effectively in situations where an insect pest problem arises from from beyond the orchard perimeter. If the pest's behavior is such that it will stop in border row trees before penetrating further into the orchard, then insecticide coverage on border row trees may give sufficient control without having to treat the whole block. In blocks with a history of low or moderate pest pressure, knowledge of hot spots, and monitoring of pest activity and the weather, this tactic may be useful for the beginning and end of the plum curculio and apple maggot egglaying periods. Until further research and grower experience demonstrates otherwise, it may be too risky to depend on border row sprays during the period of peak damage activity for these pests.

Do not spray the edge of woods adjoining the orchard. This is not legal and may disrupt habitat for pest natural enemies.

Border row treatments may not provide satisfactory control if the population of immigrating pests in the surrounding area is very large, if the border trees are small, or if they are lightly cropped. When a border-only treatment is used, monitor for pest activity inside the block to see if pests are penetrating the border.

COMMON SPRAY PROBLEMS

CALIBRATION

Problems with inadequate pesticide efficacy and phytotoxicity are often due to inaccurate sprayer calibration and pesticide dosage. Using the method described in the Sprayer Calibration section before the spray season begins reduces the chance of such errors.

COVERAGE / UNIFORMITY

Sprays applied in early morning, evening or at night are likely to result in higher deposition of chemical on the trees, and greater uniformity through the tree because: 1) wind at these times is usually less; 2) temperature is usually lower; and 3.) humidity is usually higher, resulting in less evaporation of spray droplets in flight.

Best results are obtained when the sprayer has enough fan capacity to blow the spray through the trees and at least 10 feet above the tree tops, even when operating against a 5-mph wind. The effective coverage is less than the extent of the visible mist. The mist that carries farthest from the sprayer contains very small droplets that reflect light but contain very little of the spray material.

Maximum spray deposit requires that droplets be forced against the target surface. Spray that drifts at slow speed past tree tops is not sufficient.

Excessive travel speed results in poor coverage of the more distant portions of the tree. Adjust nozzles and air vanes to obtain the desired spray pattern. Deposit uniformity can be evaluated by use of water-sensitive paper strips placed at tree top, interior and exterior canopy locations. Water-sensitive paper is available from orchard suppliers.

Sprayers with small airblast capacity can provide satisfactory coverage if trees are small and open, and not far from the sprayer. If the sprayer produces small droplet sizes (i.e. mist blowers and air shear sprayers with average droplet diameter of less than 100 microns), or has low air displacement capacity, then travel speed should be no faster than 2 mph, and sprays should be applied only when there is little or no wind.

Large trees require a sprayer with a large air displacement capacity. Match the sprayer capability to the tree size. Air displacement capacity and air speed are different components of sprayer performance.

Adequate coverage for mite control and disease prevention with summer sprays may require removal of water sprouts. This is best done before shoots harden in June, while they can be pulled by hand.

Growers contemplating use of highly concentrated sprays (low volume) should be aware of the increased difficulty in obtaining uniform coverage. Chemical deposit on foliage and fruits near the sprayer is often much higher than desired when sprays are concentrated. This is particularly undesirable with growth regulator chemicals; and where deposit on fruit might exceed legal residue tolerances at harvest; or where fruit finish might be damaged.

Relatively high water volume (not less than 1/4 Dilute Gallonage) for miticide sprays has provided better control than lower volume sprays, possibly because more mites were wetted with chemical. Relatively high volume spray should also be used in situations where redistribution of chemical by subsequent rainfall may not improve protection, such as in post-infection or eradication sprays for apple scab, streptomycin spray to prevent fire blight, or sprays for powdery mildew control.

PESTICIDE SELECTION AND TIMING

In addition to its spectrum of activity, each pesticide has a unique set of characteristics that must be considered before use. Some of the most important of these are: applicator and environmental hazards, effects on beneficial insects and mites, restricted entry and preharvest intervals, tankmix compatibility and phytotoxicity risk, previous pesticide or likely subsequent applications, residual protection, sensitivity to weather during application or to temperature for optimum performance, and resistance management.

The choice of pesticide can affect the timing of the application, or vice versa. Other factors that affect spray timing include: growth stage of tree or fruit; scouting observations; pest lifestage; activity pattern of pest or of honeybees and other beneficial species; weather conditions prior to application (e.g. scab infection period), weather during application (e.g. sterol inhibitors), or the weather forecast for afterwards (e.g. do not spray oil just before a frost).

PEST RESISTANCE TO PESTICIDES

Pesticide resistance is manifested in the orchard when there is a measurable reduction in the efficacy of a pesticide due to heritable metabolic, physical, behavioral or other traits within the pest population. Through a phenomenon called *cross resistance*, a population that has developed resistance to one pesticide can become resistant to other pesticides that are chemically similar even though the pests have never been exposed to the other materials. Also, a population may develop independent multiple resistance traits to different types of chemicals.

Once acquired, resistance may be stable, or it may decline if subsequent generations of the pest are not exposed to the pesticide. There are examples of both cases among apple pests. Apple scab resistance to dodine (Syllit) or benomyl (Benlate) is thought to be quite stable, but mite resistance to dicofol (Kelthane) can decline over several years if subsequent generations are not exposed to the chemical and the selection pressure for resistance.

In addition to fungicides and miticides, resistance is also a concern for other categories of pesticides used on apples: bactericides, herbicides, insecticides, and rodenticides.

Resistance prevention strategies: The potential for a pesticide-resistant pest population developing depends on interaction between biological and chemical factors. One consistently true rule is that reducing the number of times a pesticide is used decreases the potential for resistance to that chemical. Making full use of biological, cultural and other non-pesticidal controls is a key factor in preventing resistance because these methods suppress the pest population without the genetic selection pressure that leads to resistance. In addition, natural enemies of pest mites and insects can actually reduce resistance because the enemies attack both resistant and susceptible individuals, thereby diluting the breeding advantage of the pesticide-resistant individuals.

Because of the differences among pests and pesticides, a resistance management strategy must be tailored for each situation. A resistance management strategy that works for one class of pesticides may increase the problem if used incorrectly for others. For example, combining two types of fungicide has worked to control resistant apple scab fungus populations. This is because individual scab spores that are resistant to one fungicide are still killed by the other. But combining two or more insecticides or miticides has been found to fail because the pest insect or mite population is likely to develop resistance to all of the combined materials creating a multiply resistant pest. Rotating among products with different modes of action so that any one chemical is used as infrequently as possible is a better approach for preventing insecticide and miticide resistance.

Chemical groups with shared mode of action and cases of cross-resistant pests are:
organophosphate insecticides (azinphosmethyl, chlorpyrifos, diazinon, dimethoate, phosmet) and **carbamate insecticides** (carbaryl, methomyl, oxamyl);
pyrethroid insecticides (esfenvalerate, permethrin);
organotin miticides (cyhexatin, fenbutatin oxide);
tetrazine miticides (clofentezine, hexythiazox);
benzimidazole fungicides (benomyl, thiophanate methyl);
sterol inhibitor fungicides (fenarimol, myclobutantil, triflumizole); **strobilurin fungicides** (kresoxim methyl, trifloxystrobin).

BREAKDOWN OF PESTICIDES

In alkaline water mixture (pH above 7.0) many pesticide compounds break down to inactive forms. Carzol, Imidan, Lannate, and Vydate are known to be susceptible to breakdown if kept in a solution with pH above 7.0. Information on specific compounds is sketchy, but at pH well above 8.0, a pesticide may lose 50% or more of its effectiveness within one hour. To prevent this problem, it is important to:

- Avoid tankmixing pesticides with materials that are strongly alkaline (observe label cautions);
- Check the pH of the water source used to fill the sprayer tank; and
- Check the pH of finished tankmix combinations. Test strips that indicate pH by color change are available from pharmacies and other sources.

Use caution in attempting to acidify alkaline spray mixtures. Eight fluid ounces of 5% acid vinegar may be more than enough to acidify 300 gallons of water. Buffering additives are available that can hold the spray solution to about pH 6.0.

Weather or an equipment problem sometimes causes a delay in applying a spray load. As a general rule in this case, the tank should be applied as soon as possible to the orginally intended target. The possible effect of the delay on the chemicals in the tankmix should be considered in determining the need for subsequent application. Factors that influence this effect include: duration of the delay, pH of the tankmix, and the sensitivity of the chemicals to degradation at the measured pH.

Pesticide can also break down in storage. Labels give storage requirements, some of which are represented in Table 11.