THE APPLICATION OF PESTICIDES TO GRAPE BUNCHES

Grape and Wine Research and Development Corporation

Industry Representatives:
Kieran Murphy, Food Science Australia, Werribee, Vic
Alison Macgregor, Victorian Department of Natural Resources and Environment, Mildura, Vic

Project Managers:
Steven Barry, Australian Defence Forces Academy, Canberra, ACT
Rod Weber, Australian Defence Forces Academy, Canberra, ACT

LIKE ANY other farmer, the Australian grape grower is faced with the perennial problems of viral, bacterial, fungal and invertebrate pests. The fungus *Botrytis cinerea* is a particular concern, because it can cause severe crop loss. In order to protect their crops, growers spray their grapes with pesticides.

But the target to which the pesticides are applied constantly changes, because the shape and form of the grape bunch varies as it grows and ripens. There are three critical times during the growth season for the application of pesticide to bunches. They are capfall or flowering; pre-bunch closure, when the bunch has a loose open structure; and veraison, before harvesting, when the grape bunch is most closely packed, and the grapes soften and change colour.

Pesticides are typically applied using some sort of mechanised sprayer that works its way up and down the rows of vines. Many factors influence the chemical application process. For instance, different sprayers use more or less air for the liquid volume applied, and create larger or smaller droplet sizes. The concentration of the pesticide mixture can be varied, and it may or may not contain a surfactant. The canopy, bunch distribution and structure onto which the pesticide is sprayed can be radically different for different varieties and climates.

The Grape and Wine Research and Development Corporation asked the MISG if the application process could be modelled to give an idea of the relative importance of each of these variables. Ideally the corporation wished to provide growers with a decision framework to help them apply pesticide in the optimal manner at the three critical growth stages.

The MISG team derived simple equations describing the flow of air and droplets containing pesticide around and through bunches, determining the proportion of droplets that hit grapes and bunches, and estimating the ability of droplets to stick onto individual grapes. The group also found evidence that surfactant may help the flow of pesticide through the bunches, and came up with a hypothesis as to the best way to spray a bunch. Some work was done on providing growers with a means of deciding how best to optimise their spray.

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The Grape and Wine Research and Development Corporation supports research and development programs in several areas including wine grape production. It is funded by annual levies of about $10 million on the Australian wine industry.

Grape growing in Australia typically is undertaken by a wide range of groups from individual landowners on small parcels of land to large corporations with extensive holdings. Since solutions to the problems of grape production have to be applicable to all, they cannot place excessive demands on time, labour or capital.

The fungal disease *Botrytis* infects dying or necrotic tissue, such as the scar tissue left when the cap falls off the flowers. So fungicides need to target this tissue. Infections also tend to develop and spread at veraison, when the grapes are closely packed and undergo a series of biochemical changes and some water loss.

In fact, the packing of the grapes and their distribution on the vine are important in determining the impact of spraying. In tightly bunched grapes, such as the Chardonnay variety, *Botrytis* tends to develop more easily, and it is more difficult for spray to penetrate than with loosely bunched varieties.

The distribution of grapes on the vine varies. On minimally pruned canopies, developed for hot, dry regions, bunches occur throughout the whole two-metre canopy, but in cooler climes, where the canopies are often more closely managed, grapes tend to be restricted to a 30- to 60-centimetre band within the canopy. This distribution, and how far inside the canopy bunches occur, will determine the optimum spraying strategy.

Almost all pesticide is delivered to the grapes using mechanical sprayers pulled between the vines rows by tractor. The simplest and most widely used sprayer is an axial fan, often referred to as a traditional orchard sprayer. It produces a high volume of air, moving slowly when it leaves the machine. The droplets are relatively coarse. In an alternative sprayer, adjustable ducts distribute the air, which provides control of the direction and distance to the target grapes. Another machine used extensively in Australian viticulture is the air shear sprayer, which creates fine droplets travelling at high speed in a low volume of air. These sprayers employ more concentrated mixtures of pesticide.

The MISG team was asked to explore better ways of coating the grapes with pesticide for each of the three growth stages of grape bunches. The factors it considered included how much liquid to apply and at what concentration of pesticide; the most effective droplet size or range of sizes; the volume, direction and velocity of the air carrier; what role turbulence within the canopy might play; and whether the addition of surfactant would help the spray to coat the grapes.

The team began by constructing an equation for flow through a closed grape bunch. From this exercise, it became apparent that the velocity of the spray established a difference in pressure between the side of the bunch near the sprayer and the far side. It is this pressure difference which drives the pesticide through the bunch. Most of the

spray travels around the bunch. It is possible to calculate that for a typical closed bunch, pesticide flows through at a velocity about one hundredth of that delivered by the sprayer. In simple terms this means that only one in 100 drops is actually driven through the bunch.

A second equation provided a range of typical droplet sizes able to stick to the grapes on which they landed. When a droplet lands on the surface of a grape, the force of gravity tries to pull it off. This tendency is counteracted by surface tension—the affinity of the droplet for the surface—and can be altered by addition of a surfactant. You can calculate a critical diameter of a droplet which will stick relative to the angle of the surface it hits. (Clearly the steeper the surface, the less likely any given droplet will stick.) There is a maximum amount of pesticide that can be applied by thoroughly wetting the whole of the grape surface.

A third equation built on these first two gave a measure of the proportion of droplets of a particular size and velocity which would hit a bunch or an individual grape. Not surprisingly, heavier faster particles were the most likely to hit their target. Smaller particles stick better, but tend to blow around a lot more. It is also the smaller droplets which are more likely to move inside the bunches and coat the surfaces which are hardest to treat. But small drops carry small amounts of pesticide, so many of them are needed to do the job. (A drop of half the diameter contains only one-eighth the volume.)

Note that it is important that only some of the droplets hit and stick to the first layer of grapes in a bunch. This leaves the rest of the pesticide spray to travel through to the grapes behind. Such considerations led the team to begin thinking about an integrated model for contact between spray and grape bunches which became known as the "distributed sink model". The model included terms for pesticide flow and mixing. The grapes act as sinks in that they remove droplets of pesticide from the spray. How effective a sink any one grape is depends on its size, the droplet size, the droplet velocity and other factors.

Experimental data shows that the impact of increasing spray velocity is different at the different stages. At capfall, the higher the spray velocity, the fewer droplets retained, perhaps because the air blows the drops around the target and also tends to blow off liquid which has already landed. With the loose structure of pre-bunch closure, increasing spray velocity blows droplets away from the near side of the bunch, but increases deposition on the far side. But by the time of veraison, when the bunch has closed, increasing air velocity has no impact. The grapes are packed too tightly.

The addition of surfactant, however, alters the capacity of the liquid to move through the bunch from front to back at both the pre-bunch closure and veraison stages. When the team calculated the forces at work, it appeared that without surfactant the conditions would promote the formation of stable liquid bridges in the open spaces between the grapes. So even though the bunch is not completely closed, it effectively acts as if it were closed. Perhaps the surfactant acts to open up these bridges, allowing freer movement.

The group also hypothesised that spraying from the direction of the stalk may assist penetration of the pesticide into the centre of the bunch. Spraying down the stalk would also be the easiest way to coat the vulnerable, necrotic tissue around where the grape joins the bunch. This may not be practically possible, however. Not only would it be difficult to set machinery to achieve this, but it could also lead to high runoff of pesticide onto the ground.

Several members of the team thought about how to develop a simple decision-tree structure to help growers determine the optimum conditions for spraying, such as concentration of pesticide, speed of spraying, number of nozzles and so forth.

Kieran Murphy from Food Science Australia was pleased with the outcome. “I found the process exciting. The whole week was alive with new thought. We talked about and modelled many of the basic questions which have been on my mind for quite some time—aerosols, their impact, their movement and how the liquid film redistributes itself. I expect to be back next year with another problem.”