Introduction
Viticulture is an integrated system, and, it follows that vineyard management is an integrated practice. Two main characteristics of this system influence the outcome of any best practice in viticulture. Firstly, the individual components of a viticultural system are interdependent and often in dynamic equilibrium with each other. Secondly, many of these components are cyclical in nature. For example, disease management, which is a component of the viticultural system, exhibits these two characteristics because:

- disease pathogens often inhabit their ecological niches in dynamic equilibrium with other resident organisms, and,
- diseases are normally cyclical in nature where there is really no beginning and no end, but rather periods of activity and inactivity.

This may mean that it is not possible to eradicate diseases totally from an area due to the formation of resting structures by the pathogens that are often difficult to eliminate. Therefore, best practice or best result in disease management may often mean significant but only temporary control of the problem.

One of the indicators of best practice in disease management is rational use of fungicides designed to have maximum effect on the pathogens. A strategy to use fungicides rationally is based on knowledge of:

- epidemiology of disease, and
- occurrence of fungicide resistance.

An example of a disease where best practice to avoid fungicide resistance can be achieved is the botrytis rot of grapes.

Epidemiology of botrytis rot disease
The disease cycle begins with primary infection of flowers or damaged plant tissues (Nair 1990). The pathogen causes little or no harm to the crop at this stage as it lives in harmony (as a biotroph) with the host plant (grapevines). A rare exception to this is if flower infection reaches epidemic proportions, which may lead to bunch thinning and therefore loss of yield potential. In such instances, the pathogen behaves as a necrotroph. However, in Austrailia the pathogen acts as a necrotroph only on grape berries.

After primary infection, the pathogen goes into an inactive period (latent phase) in the disease cycle after fruit set. This is because the immature berries are relatively more resistant to infection. Grapevines also produce substances, such as stilbenes, in young berries which can inhibit the growth of Botrytis (Nair and Hill 1992).

Botrytis resumes its growth after veraison causing rotting of maturing berries. The amount of rotting increases with increasing concentration of sugars in the berries (Nair and Hill 1992). Disease severity also increases if the bunches have been damaged by insects such as caterpillars of lightbrown apple moths or adverse weather such as hail storms (Nair et al. 1988).

After harvest the pathogen goes into a dormant phase during winter by producing resting structures called sclerotia, on the canes, or as mycelium. These sclerotia are capable of germinating to produce spores which cause primary infection of flowers or damaged plant tissues during the following spring, thus initiating the disease cycle in the next season (Nair and Nadotchei 1987).

The teleomorph (sexual form) of Botrytis is an ascomycete called Botryotinia fuckeliana and is thought to have a limited role in the disease cycle.

Fungicide resistance
Fungicide resistance is a reality for at-risk chemicals and a threat to many more. Resistance arises through selection of differences in sensitivity already present in natural populations of pathogens prior to the introduction of a new fungicide. Once resistance arises, it is inheritable. Normally a resistant mutant or mutant strain of the pathogen might be present at an initial frequency of the order of 1 in 1000 million spores. It is only when the population of the resistant strain reaches 1 in 100 (1%) or even 1 in 10 (10%) that disease becomes difficult to control and these resistant individuals are readily detectable. When this happens, the next fungicide treatment is likely to fail to give disease control.

There are three main purposes of monitoring fungicide resistance:

- early warning is considered to be one of the purposes of resistance monitoring. However, single-step resistance (e.g. benzimidazoles) only becomes readily detectable when a relatively high level of resistance is reached. Therefore early warning is difficult to obtain. With multi-step resistance (e.g. DMIs), however, partially resistant strains can occur at a high level before disease control fails. In such instances early warning is possible. If the pathogen has a slow rate of reproduction, early warning may be obtained. If the resistant strains are less fit (e.g. dicarboximides), the build-up of resistance may be slow and useful warning is possible.
- another purpose of monitoring resistance is to check that disease management strategies are working properly.
- monitoring fungicide resistance also helps in investigating suspected cases of outbreaks of resistance. This is done by monitoring at specific sites.

Best practice to avoid fungicide resistance involves steps to:

- prevent, delay or manage fungicide resistance in order to maintain the shelf-life of fungicides;
• foster a responsible attitude towards resistance problems among growers and encourage them to use fungicides in a rational manner; and,
• demonstrate the role played by fungicide resistance management strategy in disease management.

Fungicide resistance in Botrytis cinerea
Botrytis can develop resistance to modern at-risk fungicides, but does not develop resistance to multi-site fungicides. Factors of concern regarding fungicide resistance in Botrytis are:

• a short pathogen cycle;
• a freely sporulating target pathogen;
• haploid asexual stage and therefore expresses resistance directly—no possibility of masking by a dominant gene;
• multinucleate nature with an average of 4–5 nuclei per spore—leading to resistance at different levels;
• the need for frequent, widespread application of fungicides; and,
• the ability to survive out of season.

Best practice to avoid resistance in botrytis rot of grapes
In spite of the complexities in the biology of Botrytis and its mode of resistance, we have good knowledge of the epidemiology of botrytis rot of grapes as well as seasonal dynamics of resistant populations of Botrytis to be able to adopt best practice for management of the disease. Its success will, however, depend on adopting an integrated approach involving:

• disease risk assessment by monitoring Botrytis incidence (Nair et al. 1995);
• canopy management to increase ventilation (Somers and Nair 1995); and,
• plant hygiene by reducing carry over of disease.

Guidelines for best practice to avoid fungicide resistance in the management of botrytis rot of grapes are given below.

Export market
Pre flowering
Fungicide application at this stage is only necessary if there is a high carry over of Botrytis inoculum from the previous season. The level of inoculum can be determined from Botrytis monitoring test. A void application of fungicides at this stage that are likely to cause resistance. Use multisite fungicide (e.g. chlorothalonil, Bravo®); this is a protectant and acts to prevent primary infection of flowers. Chlorothalonil may discolour white grapes and delay fermentation of wine if it is used after berry set and within fourteen days of harvest respectively.

80% cap fall
Use benzimidazoles (e.g. Benlate®, Spin® etc.) if resistance to this chemical group is low or absent; otherwise use anilinopyrimidines (e.g. Scala®). The purpose of applying these chemicals is mainly to eradicate latent infection established earlier at flowering. Save dicarboximide for later application. If Bravo® is used, several frequent applications may be necessary in order to protect the growing shoots from infection. Sumisclex®, a dicarboximide, can only be used if not intending to export to Canada (see editors’ postscript).

End of flowering (Optional)— monitor dicarboximide resistance at this stage if resistance has been relatively high at previous monitoring (at harvest of last season).

Pre-bunch closure (before berries touch)
Apply dicarboximide (e.g. Rovral®) before berries touch if dicarboximide resistance is low or absent; otherwise use anilinopyrimidines (Scala®) after checking MRLs in USA and Canada. Sumisclex® can only be used if the export market is not Canada (see editors’ postscript).

Veraison
Apply a dicarboximide (e.g. Rovral®), if anilinopyrimidine (e.g. Scala®) has been applied twice already (i.e. at 80% cap fall and pre-bunch closure); otherwise use anilinopyrimidine (e.g. Scala®) after checking MRLs in USA and Canada. Use Sumisclex® if not intending to export to Canada (see editors’ postscript).

Pre-harvest
If anilinopyrimidines (e.g. Scala®) has been applied twice previously, use dicarboximide (e.g. Rovral®). Use Sumisclex® if not exporting to Canada (see editors’ postscript).

Harvest
Monitor resistance to benzimidazoles, dicarboximides and anilinopyrimidines.

(Omission of any commercial botryticide product in the protocol is unintentional)

General rules (refer AVCARE guidelines)
Do not apply more than 2 unmixed Group AT or Group BT fungicides.

Group I* fungicides: 1 out of 3 other in season sprays, or 2 out of 4 other in season sprays.

Group A = benzimidazoles
Group B = dicarboximides
Group I = anilinopyrimidines

Home market
Follow the same protocol as for export market. MRL restrictions may not apply; however, this requires confirmation.

Editors’ postscript
Sumisclex now has a seven-day withholding period.

References