THE ENVIRONMENTAL BEHAVIOUR OF HERBICIDES IN AUSTRALIAN VITICULTURE

by

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Herbicides have been used widely in the control of weeds in South Australian vineyards. Due to the persistence and movement of the herbicides after application, they can cause some environmental problems. They may contaminate water through leaching and run-off. They may also damage vines and contaminate grapes and, in some cases, the wine made from contaminated grapes will also be contaminated.

This thesis reports on the results of a study on the environmental behaviour of several herbicides viz. norflurazon, oxadiazon, oxyfluorfen, trifluralin and simazine used in South Australian viticulture. The mobility and degradation of these herbicides were assessed through a combination of laboratory and field experiments. The fate of the herbicides from vine to wine was also investigated. A proposal for good environmental management of herbicide use in vineyards in order to minimise the effects of herbicide residues in the environment has been developed.

Sorption of herbicides is an important process that occurs in soils following application. The sorption coefficients of norflurazon, oxadiazon and trifluralin in several key soils from the Barossa Valley ranged from 3.48 to 5.27 for norflurazon, from 16.07 to 23.38 for oxadiazon, and from 189.63 to 310.78 for trifluralin. Trifluralin had high sorption on the soils while norflurazon had low sorption on these soils. Sorption tests on suspended sediments in water showed that higher percentages of the herbicides were sorbed under stirred conditions than under non-stirred conditions. Sorption of the herbicides on soils or suspended sediments was in the following order: trifluralin > oxadiazon > norflurazon. This study also showed that the herbicides could be strongly adsorbed by charcoal.

Laboratory studies on packed soil columns indicated that the decreasing order of leaching potential of the herbicides in soils was: norflurazon > oxadiazon > trifluralin > oxyfluorfen. The timing of rainfall or watering following herbicide
application had an effect on the leaching of the herbicides. The shorter the time interval between herbicide application and watering (or rainfall), the further and more quickly the herbicides (eg. norflurazon) moved in soil.

Laboratory studies on intact soil columns from the Mountadam, Nuriootpa and Koonya vineyards showed that simazine and norflurazon leached from the sandy soil columns after two weeks of 26 mm “daily rainfall”. Distribution of herbicides in soil profiles after leaching clearly showed that norflurazon and simazine moved to the bottom of the soil columns while trifluralin, oxadiazon and oxyfluorfen remained mainly in the top of soil profiles (0-10 cm).

Leaching studies on dry intact soil columns from Kalimna and Koonya Hill vineyards showed that norflurazon and simazine could leach out by rainfall or irrigation in clayey soils without wetting the soil columns before herbicide application. Non-equilibrium and preferential flow were believed to be responsible for the leaching of norflurazon and simazine in clayey soils. It is confirmed in this study that a herbicide mixture (norflurazon with other herbicides) reduced the leaching of norflurazon in soil. More norflurazon was leached from the intact soil column to which only norflurazon was applied than from the intact soil column with the mixed herbicides under the same conditions.

The dissipation rates of the herbicides in the field varied from one year to another. The dissipation half lives ranged from 2 weeks for oxadiazon to 16 weeks for oxyfluorfen in the Mountadam vineyard soil. Oxyfluorfen was the most persistent herbicide, while oxadiazon, trifluralin and norflurazon dissipated relatively faster in the soil. The distribution of herbicides in soil profiles after application showed that the herbicides (norflurazon, oxadiazon and trifluralin) stayed in the top soil layers before the onset of rain, and that they were leached in the soil profiles to different extents due to their different physiochemical parameters.

Herbicides in shallow groundwater following application were monitored using installed lysimeter tubes in the Mountadam vineyard. The herbicides (norflurazon, oxadiazon, trifluralin and oxyfluorfen) were detected in the shallow groundwater in
the first year following application, while only norflurazon was detected in the following year. The concentration of norflurazon in groundwater was high, but the concentrations of oxadiazon, trifluralin and oxyfluorfen were relatively very low, ranging from several ppb to tens of ppb in the groundwater. The concentrations of the herbicides were correlated positively with the weekly rainfall. Norflurazon was found to be the only herbicide which moved laterally from a plot 7 meters away from the lysimeters.

Laboratory and field studies showed that simazine and norflurazon were relatively more mobile, and oxadiazon, trifluralin and oxyfluorfen less mobile in soils. The leaching potential of the herbicides in soil was in the following order: simazine > norflurazon > oxadiazon > trifluralin > oxyfluorfen. Movement of the herbicides could result from mass flow or from preferential flow and non-equilibrium partitioning through soil matrices as well as macropores.

The half lives for photolysis of the herbicides in soil ranged from 3.53 days for trifluralin to 5.53 days for norflurazon. However, the herbicides degraded more rapidly in water under sunlight. Trifluralin and oxyfluorfen photodecomposed very rapidly in de-ionised water with half lives of 2 hours for trifluralin and 4.8 hours for oxyfluorfen. Norflurazon and oxadiazon photodecomposed more slowly than trifluralin and oxyfluorfen, with half lives of 1.53 days for norflurazon and 2.62 days for oxadiazon in water. The addition of H₂O₂ in water did not have obvious effects on the photolysis of norflurazon and oxadiazon studied in water. However the photolysis of norflurazon and oxadiazon was retarded in natural water due to sunlight attenuation by organic and inorganic matter in water. Several photoproducts were identified by GC-MS after photolysis of each herbicide (norflurazon, oxadiazon and oxyfluorfen) in water under sunlight. The photochemical pathways mainly involved the loss of small functional groups such as chlorine atoms, methyl and nitro groups.

The study on herbicide residues in red and white grapes from the Roseworthy Campus vineyard and the Nuriootpa Research Station showed that norflurazon and oxadiazon dissipated much more slowly than oxyfluorfen and trifluralin on grape
surfaces. Trifluralin and oxyfluorfen were not detected in grapes from Roseworthy Campus vineyard 4 days after treatment, but remained in red grapes from Nuriootpa Research Station vineyard as long as one week. Norflurazon and oxadiazon residues remained in grapes for as long as one month. White grapes were found to retain more herbicide residues on their surface than red grapes due to the different textures and surface waxes of red and white grape surfaces. About 14% of norflurazon was found to have penetrated into grape flesh in the white grapes, while only 1.47% of norflurazon penetrated into grape flesh in the red grapes.

Treated and untreated red grapes from Nuriootpa Research Station vineyard were used to make wine at the Roseworthy Campus winery. This facet of the study showed that the herbicides viz. norflurazon, oxadiazon, trifluralin and oxyfluorfen did not have obvious effects on fermentative microflora. Oxadiazon, oxyfluorfen and trifluralin degraded more rapidly in red wine than did norflurazon. The herbicides, except for norflurazon, were not detected after 24 days, but norflurazon was present in the finished wine. Herbicide-contaminated wine could be cleaned up using charcoal with diatomaceous earth during wine making processes, or with a cellulose pad before bottling.

Finally, arising out of the results of this research, some suggestions on good environmental management in viticulture were proposed, these included: (1) choose appropriate herbicides and use the minimum dosage, (2) properly apply the herbicides, (3) avoid damage to vines and contamination of grapes, and (4) avoid damage to the environment. In order to reduce possible leaching of herbicides in soil, it is better to choose less mobile and rapidly degraded herbicides. Caution should be exercised in using mobile herbicides such as simazine and norflurazon in sandy soils. Herbicides should not be applied either on rainy days, or when there will be rain in the following several days after application. Herbicides should also not be applied too close to grape harvest in order to avoid contamination of grapes in vineyards. Before applying herbicide, such factors as herbicide properties, soil type, weed species and weather conditions need to be considered.