Wine & Viticulture Journal

Publication (Sep/Oct 2017)

How do herbicide drifts affect your grapevines: symptoms and vine sustainability

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A 12-month study is about to begin that will simulate drift of various herbicides on potted vines to monitor the visual response of the plants to each herbicide, particularly on foliage, shoots and fruit, and study the repercussions on leaf functioning. The aim is to produce useful guidelines for growers to identify grapevine injury from specific herbicides and improve understanding of grapevine response in the short term and in the following season.

INTRODUCTION

Grapevines exhibit phytotoxicity towards various herbicides used against invasive weeds on broadacre crop production farmland, roadsides, and lawns. Grapegrowers in diversified cropping regions may encounter herbicide drift exposures to their vineyards, sometimes during sensitive periods such as around early shoot growth or flowering. As a result, seasonal and interseasonal detrimental effects on vegetative development, grape yield and composition, and economic sustainability, may occur. However, identifying the herbicide causing a specific injury symptom is challenging and little is known about how herbicide exposure affects grapevine metabolism and berry composition. Our research attempts to assess the implications of herbicide exposure on visual grapevine symptoms in conjunction with physiological and biochemical responses.

HERBICIDE TYPES OFTEN CAUSING GRAPEVINE INJURIES: HOW THEY WORK

Herbicide drifts, especially those of the phenoxyacetic acid group, can move substantial distances (several kilometres) depending on the prevailing weather conditions (wind, temperature and relative humidity), the herbicide formulation (e.g. ester or amine form), and details of the spray application process, for instance nozzle type and sprayer setup (Felsot *et al.* 2011). When phenoxyacetic acid herbicides are sprayed in an ester formulation, volatile vapours are easily produced particularly due to inversion layers in the atmosphere.

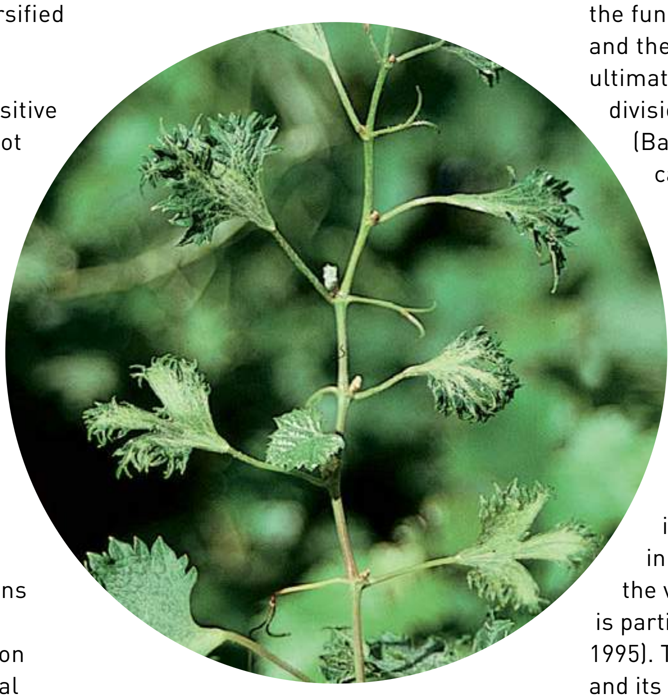

Figure 1. Small, fan-shaped leaves from 2,4-D or glyphosate damage. Copyright: Peter Magarey/Winetitles

With regard to different phenoxyacetic acid herbicides, 2,4-dichlorophenoxyacetic acid (2,4-D), a synthetic form of the plant growth hormone auxin, is particularly renowned for causing widespread grapevine injuries (Figure 1 and Table 1, see next page). Auxins regulate plant growth and development, particularly aspects such as cell division and enlargement. Synthetic auxins mimic the functioning of the natural hormone, and the damage after absorption ultimately causes uncontrolled cell division in developing plant tissues (Baumann *et al.* 1999). In some cases, particularly when the exposure occurs during early shoot growth or around flowering, 2,4-D exposure can induce severe loss of fruit yield (Read and Gamet 2016). Another example of a powerful phenoxyacetic acid herbicide is 2-methyl-4-chlorophenoxyacetic acid (MCPA). Like 2,4-D, when MCPA is sprayed as an ester rather than in an amine or salt formulation, the volatile vapour drift potential is particularly noteworthy (Dexter 1995). The mode of action of MCPA and its effects on grapevine vegetative development are comparable to that of 2,4-D. Dicamba, or 3,6-dichloro-2-methoxybenzoic acid, is another growth regulating herbicide widely used in crop fields. Dicamba also functions as a synthetic auxin, with a benzoic acid derivative as the active ingredient. The detrimental effects of auxinic herbicides are especially noteworthy during stages of active shoot growth, as the synthetic auxins readily translocate to tissues undergoing rapid growth. ►

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Glyphosate-based herbicides are probably one of the best-known types of weed killer around the world. Although glyphosate vapour drift is less likely to travel extensive distances compared with drifts associated with phenoxyacetic acids, suitable conditions may induce glyphosate spread towards adjacent areas (Felsot *et al.* 2011). Glyphosate is also often applied within vineyards due to its effectiveness against a wide range of problematic weeds which are commonly found in vine rows. When grapevines are exposed to glyphosate, primary plant functioning is directly affected due to the herbicide's mode of action, inhibiting the 5-enolpyruvylshikimate-3-phosphate synthase (EPSPs) enzyme which is involved in the shikimate pathway (Siehl 1997). Inhibition of this enzyme causes shikimate accumulation in the plant and blocks the biosynthesis of the aromatic amino acids (phenylalanine, tyrosine and tryptophan). Aromatic amino acids play precursor roles in the synthesis of vital plant compounds such as polyphenols (Donnini *et al.* 2016) and is, therefore, needed for the biosynthesis of secondary metabolites such as anthocyanins and tannins. The biosynthesis of aromatic amino acids such as phenylalanine is, for example, ultimately required for the skin colour development of red grape varieties.

Table 1. Commonly used herbicides in Australia, categorised based on the herbicide type and mode of action.

Herbicide active ingredient	Type	Mode of action
2,4-dichlorophenoxyacetic acid (2,4-D)	Plant growth regulators (phenoxyacetic acids)	Synthetic auxins: mimic the function of natural plant auxins, causing hormone imbalances and abnormal vegetative growth.
2-methyl-4-chlorophenoxyacetic acid (MCPA)		
6-dichloro-2-methoxybenzoic acid (dicamba)	Plant growth regulator (benzoic acid derivative)	
Glyphosate	Amino acid inhibition	Blocks the synthesis of the aromatic amino acids, which are precursors of essential plant metabolites.

HERBICIDE EXPOSURE SIGNS AND EFFECTS ON GRAPEVINES: WHAT WE DO AND DO NOT KNOW

Although the modes of action of the above-mentioned herbicides are well documented, the signs of grapevine exposure to different herbicide types are easily confused (Table 2, see page 55), particularly in terms of symptoms caused by different growth regulating herbicides. Therefore, the overall aim of this research is not only to produce guidelines useful for growers to identify injury signs linked to specific herbicides, but also to improve our understanding of the grapevine response, in the short term and in the following season. We want to evaluate how vine physiology and metabolism change when herbicide exposures occur, in conjunction with the specific morphological injuries they cause.

It is recognised that plant metabolism may be altered by exposure to herbicides. This could happen either directly by altering the carbon flux through certain metabolic pathways (Siehl 1997, Magalhaes *et al.* 2017), or indirectly by changing the grapevine canopy carbon assimilation efficiency through impairments in leaf stomatal (pore) functioning (Bondada 2011). The systemic nature of these herbicides also mean that active constituents are translocated through the entire plant (Baumann *et al.* 1999, Shaner 2009). Foliar absorption of herbicides may, therefore, subsequently alter vine physiology and metabolic pathways in other organs, such as the roots and fruit. However, primary carbon metabolite profiling of different grapevine tissues in response to herbicide injury has not yet been investigated. Little is thus known about the fundamental response of grapevines to these herbicides, particularly in relation to vine sensitivity at key stages of the season. Herbicide translocation in the permanent structure of the vine may also result in detrimental effects into the following season, potentially impacting critical aspects such as bud fruitfulness and fruit yield (Ogg *et al.* 1991). Essentially, our objective is to investigate the implications of the herbicides on central grapevine functioning to improve our understanding of what happens in the vine, both when these injuries occur and during recovery. This will allow us to devise protocols that growers can implement if and when such exposure and injury occurs.

WHAT ARE WE GOING TO DO?

A study using potted vines has been initiated at the National Wine and Grape Industry Centre at Charles Sturt University. The 12-month study, funded by Wine Australia's Incubator Initiative, will be conducted in collaboration with the NSW and ACT regional cluster as industry partners. Experimental work will commence in late spring at the termination of flowering. Simulated herbicide drifts will be created under controlled conditions within an automated cabinet sprayer which will deliver a precise volume of herbicide to each grapevine. These drift applications will replicate what happens in the field in terms of probable vapour movements of 2,4-D, MCPA, Dicamba and glyphosate, similar to common herbicide application rates in broadacre farmland in proximity to a hypothetical vineyard. The application rates will represent severe but realistic drift incidents (Al Khatib *et al.*1993, Mohseni-Moghadam *et al.* 2016). The post-flowering period was chosen because this phenological stage coincides with noteworthy grapevine herbicide injury incidents throughout grapevine growing regions in NSW.

The first key objective of the study will be to monitor the development of visual injury symptoms in response to each herbicide as the season progresses, with emphasis on foliage, shoots and fruit. Detailed images and visual references will be collected for each known herbicide exposure. The second objective will be to study the repercussions of the different

Table 2. Grapevine leaf and fruit injury symptoms reported to result from exposure to growth regulating herbicides and glyphosate.

Herbicide	Typical grapevine injury symptoms
Growth regulators (2,4-D, MCPA and dicamba)	Leaves: small, narrow and deformed (fan shaped, downward bending and curled). Thick veins that lack chlorophyll, with reduced interveinal spaces. Upward cupping of younger leaves. Fruit: Reduced set and delayed/uneven ripening. Downward bending of bunches. (Al-Khatib *et al.*1993, Bondada *et al.* 2011, Mohseni-Moghadam *et al.* 2016)
Glyphosate	Leaves: distorted shape (fan-shaped with crowded veins), interveinal chlorosis and cupping. Necrosis of leaf margins. Fruit: Flower abortion, reduced skin anthocyanins (red colour). (Al-Khatib *et al.* 1993, Ball *et al.* 2014, Donnini *et al.* 2016, Mohseni-Moghadam *et al.* 2016)

herbicides on leaf functioning. Finally, the grapevines will be dismantled into their key components at key stages of the season, i.e. fruitset, veraison and fruit maturity. These samples will be assessed for the repercussions of the different herbicides on short- and longer-term leaf, berry, and root primary metabolism. Furthermore, fruit yield and composition, carbohydrate reserve storage, and bud fruitfulness for the next season will be assessed.

CONCLUSIONS: WHAT PRACTICAL SOLUTIONS DO WE HOPE TO FIND?

We aim to produce a field guide that grapegrowers can use to promptly recognise specific herbicide drift exposures as soon as they occur, and also to help avoid future herbicide incidents at sensitive stages of the season. The initial potted vine study will provide a broad spectrum of information required to understand the underlying physiological and metabolic implications of specific herbicide exposures in spring on grapevines. Such an initial understanding is needed to develop future strategies aimed at avoiding or minimising grapevine herbicide damage. The information can subsequently be used to better engage with neighbouring farmers to avoid the spraying of specifically-identified problematic herbicides during critical periods of the season, thereby avoiding potential herbicide drift induced yield losses and altered grape composition in the future. The intention is also to build upon the preliminary results of this small-scale study by conducting targeted studies in established vineyards in future seasons.

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