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Auxin-type herbicide drift: effects on grapevine leaf functioning and reproductive performance

>>> Auxin-type herbicides are widely used to control broad-leafed weeds in cereal crop fields and pastures. Vapour drift, however, can spread several kilometres and therefore reach nearby vineyards. When grapevines are exposed to these chemicals, the active constituents induce phytotoxic effects including injury to foliage and impairment of reproductive development. The aim of this article is to outline the key potential implications of auxin-type herbicide drift exposure on leaf functioning and grapevine reproductive performance. <<<

■ Auxin-type herbicides: modes of action

Under physiological levels, the natural plant hormone auxin is crucial for regulating cell division, differentiation and elongation. Conversely, when present in supraphysiological concentrations, auxins may damage developing plant tissues and cause necrosis or even plant death (Figure 1). Synthetic forms of the hormone are therefore used as herbicides. The auxin-type herbicides include 2,4-dichlorophenoxyacetic acid (2,4-D), 2-methyl-4-chlorophenoxyacetic acid (MCPA), and dichloro-2-methoxybenzoic acid (Dicamba).

The herbicides are absorbed through the leaf stomata and by roots from residues in soil. Once absorbed, the compounds are translocated to growing tissues including shoots and leaves[1]. When accumulating to supraphysiological levels, the auxins induce uncontrolled cell division. Furthermore, once a critical level of auxin is reached, ethylene is produced which in turn inhibits tissue growth[1].

■ Occurrence of spray drift and key repercussions for grapevines

When herbicides are sprayed in the field, volatile vapours are spread due to inversion layers in the atmosphere (Figure 1). These vapour particles can drift several kilometres off-target, particularly under warm atmospheric temperatures, a low relative humidity, and especially, in prevailing winds[2]. In general, the herbicides with an ester formulation exhibit an increased volatilisation potential compared to the amines and are therefore more likely to induce a significant drift[2].

It is not unusual for herbicide spray drift to reach vineyards and consequently for the growth and development of grapevines to be impaired. The active constituents of the auxin-type herbicides accumulate in plant tissues undergoing rapid growth[1]. Therefore, in conjunction with the herbicide formulation and drift rate, the phenological growth stage of the grapevines when herbicide exposure occurs, is likely to determine the severity of the related injuries. Grapevine leaf development and functioning[3], shoot growth[4], and fruit yield[5] are possibly impaired when grapevines are exposed to auxin-type herbicides.

■ Foliar injuries associated with auxin-type herbicides

Foliar injuries as induced by different auxin-type herbicides are not easily discerned in grapevines[6]. This is likely attributed to the fact that these different herbicides share similar chemical and functional properties[1]. However, we have described signs of grapevine injury specific to 2,4-D, Dicamba, or MCPA exposure, around flowering[6] (Figure 2). Symptoms of leaves exhibiting 2,4-D injury include upward rolling or cupping of young leaves, interveinal white or yellow lesions, a fan-shaped appearance, reduced interveinal spaces, and/or discolouration around the veins (Figure 2A). Injuries caused by Dicamba are likely to resemble leaf blade rolling in conjunction with the development of yellow and brown interveinal lesions (Figure 2B). Exposure to MCPA may induce leaf folding or rolling, whilst the young expanding leaves may show signs of epinasty (Figure 2C). Furthermore, interveinal chlorotic lesions may emerge in conjunction with necrosis of the leaf margins.

In addition to the visual signs of injury, the functioning of grapevine leaves may also be impaired. In fact, stomatal abnormalities[3], and reduced chlorophyll abundance and photosynthesis rates[7], are probable repercussions. Such impairment of leaf functioning may limit the production of carbohydrates, which may consequently hinder vegetative growth, bud fruitfulness and berry sugar accumulation, depending on the stage of development at the time of exposure.

■ Implications of auxin-type herbicides on reproductive development

Since grapevine reproductive development extents over two consecutive growing seasons, spring-time exposure to auxin-type herbicides may reduce the fruit yield in the current season and have a potential carry-over effect for the next season in regard to further yield reductions[5]. In terms of the current season, reduced fruit set and consequently smaller and fewer berries per vine may be the result[3, 7]. In addition, partial or full necrosis of bunches may occur, thereby further reducing the fruit yield[7].

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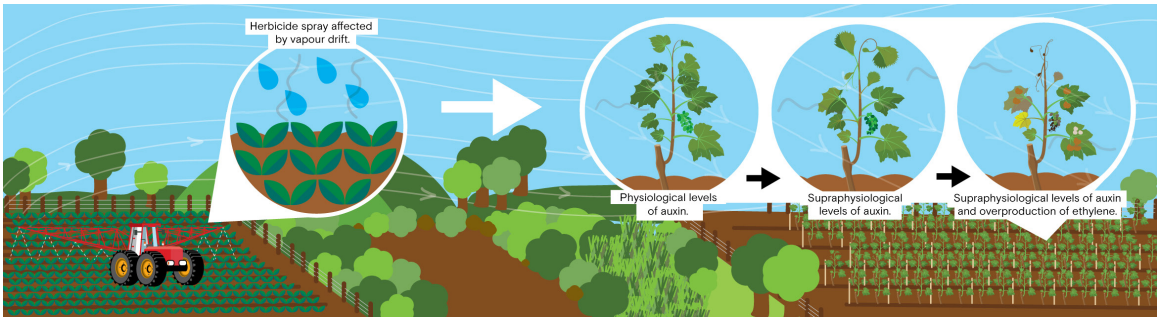

Figure 1. Illustration of auxin-type herbicide drift reaching a vineyard. The herbicides induce excess levels of auxin in grapevines causing uncontrolled cell division in growing tissues. Young leaves may consequently exhibit a fan-shaped appearance in conjunction with bending of shoot tips and curving of bunches. An overproduction of ethylene follows, and shoot tip, leaf and bunch necrosis may occur.

The extent of yield loss following a drift event is likely proportional to the rate of herbicide exposure. Herbicide drift may also compromise the berry composition by fruit maturity, potentially leading to uneven or delayed berry maturation[5] and elevated levels of titratable acidity[7].

Regarding the next season, exposure to auxin-type herbicide drift may promote the development of necrotic tissues within grapevine compound buds, including an increase in incidence of primary bud necrosis (PBN)[7]. Among three auxin-type herbicides studied in a recent experiment, 2,4-D was particularly detrimental to the health of compound buds[7]. Compared to unsprayed vines, 2,4-D exposure at 7 % of the recommended label rate, induced a significant increase in the proportion of buds exhibiting necrotic tissues by veraison. This was regardless of the position of the buds along canes of the 48, five-year old potted Tempranillo grapevines used in the study (Figure 3A). Here, the presence of any necrosis was assessed irrespective of the location across the primary, secondary or tertiary buds. Furthermore, by fruit maturity, 2,4-D drift induced an increase in PBN, that is, the death of the primary bud, especially for those buds located toward the shoot apex (Figure 3B). As a result of PBN, fruitfulness for the following season is potentially compromised. The fruitfulness of compound buds located toward the apical end of shoots may be impeded to a greater extent compared to those near the base following a drift event around the flowering period[7].

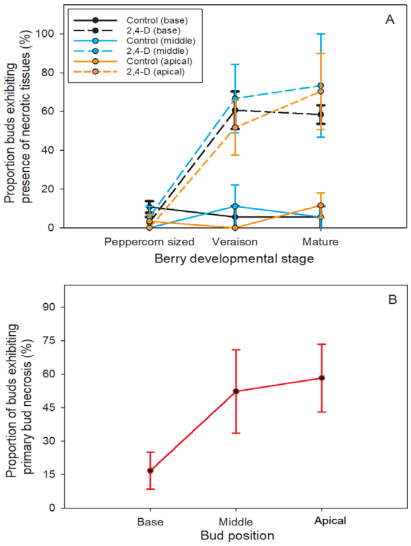

Figure 3. Impact of 2,4-D drift (0.1 L/ha), A) compared to an unsprayed control, on proportion of buds exhibiting necrotic tissues (to any extent). Injury was assessed when the berries were peppercorn sized, the start of veraison, and fruit maturity, that is, 1, 5 and 10 weeks after drift, respectively; B) on proportion of buds exhibiting PBN (complete death of the primary bud) near the base, middle and apical part of canes, at fruit maturity (mean ± SE).

■ Mitigating the damage

The spring period, when rapid grapevine shoot growth occurs, poses a considerable risk for herbicide drift damage in vineyards. Grape growers should take precaution to avoid off-target exposure of grapevines to herbicides, particularly around the sensitive flowering period. The buds located near the apical region of shoots are more likely to become necrotic, and thus less fruitful, if an auxin-type herbicide related drift event occurred during the period of active shoot growth. Therefore, the yielding capacity of cane pruned grapevines for the next season are likely to suffer more in such cases. Spur pruning may be a more suitable option for vineyards which are regularly affected by auxin-type herbicide drift during spring and early summer. ■

Figure 2. Grapevine (*Vitis vinifera L.* cv. Tempranillo) leaves exhibiting signs of 2,4-D (A), Dicamba (B) and MCPA (C) injury. Signs of 2,4-D injury include upward leaf cupping, serrated margins and discolouration around veins. Injuries associated with Dicamba exhibit upward curling of leaf margins, and yellow and brown interveinal discolouration. Injury related to MCPA includes interveinal white spots.

Gerhard Rossouw[1], Suzy Rogiers[2], Bruno Holzapfel[2], Leigh Schmidtke[1]
1 National Wine and Grape Industry Centre, Charles Sturt University, Australia.
2 NWGIC, Department of Primary Industries-NSW, Australia.

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