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Deposit variability and prediction in fruit crops: What use are label rates anyway?

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Summary

Two-fold variations in leaf and fruit spray deposits are typical between the inner and outer portions of winegrape, apple and citrus canopies, even after spray plumes are optimised for the target. Agrochemical application rate recommendations are established through field efficacy trials in which deposits and their variability are not quantified. In most cases rates are established for dilute spray mixtures applied to the point of runoff. However, operator perceptions of coverage, runoff, application volume and sprayer setup requirements vary widely between canopies and with different sprayers. The chemical label rate per 100 litres of dilute spray mixture provides the most consistent information from which growers can determine application rate requirements. However, simple systems are required from which growers can adjust application rates in relation to canopy and sprayer effects on deposits. Sources of between-canopy deposit variability and their mitigation are discussed with reference to winegrape, apple and citrus crops.

Key words: spray deposits, dose, application rate, winegrape, apple, citrus

Introduction

Spray application requires a large, and usually unrecognised, leap of faith on the part of the sprayer operator, who receives little feedback on how the spray was distributed on the target canopy or what dose was achieved. Application rates and volumes tend to become set in relation to individual and regional grower experience. However, the control outcomes are influenced by multiple variables of which application rate and volume is just a part. Growers have no information as to what application volumes and chemical rates are actually required.

Interpretation of chemical labels

Chemical rate per 100 litres of dilute spray volume is the key piece of product label information from which growers make application rate decisions. Chemical rates per 100 l of dilute spray hold some inherent variations that reflect the inconsistencies between, and lack of standards for, chemical testing methods and canopies used when chemicals are tested for registration. For example, of 42 different fungicide products registered for possible use on wine grapes in NZ, 22 labels prescribe minimum rate or water volume per hectare recommendations. Interpretation of the hectare rate label statements in terms of recommended application volumes gave suggested volumes that varied between 1,000 and 1,500 litres ha^{-1}.

Application rate adjustments on the basis of canopy descriptors

Delivery of consistent agrochemical doses to different sized canopies should provide more consistent outcomes than would be achieved without volume/chemical rate adjustments for tree size. There have been many attempts to identify parameters to describe different canopies as spraying targets including; leaf area index (LAI), leaf area density (LAD), height, Tree-Row-Volumes (TRV), canopy wall surface area and canopy row length. Cross *et al.* (2001) summarised TRV volume rate adjustment factors (i.e. the volume of canopy that is assumed to be effectively covered per litre of spray) that have been used in different countries. TRV's on three typical English intensive apple canopies examined by Cross *et al.* (2001) ranged from ca. 8,500 to 19,000 m^3 ha^{-1}. In an evaluation of the TRV approach Manktelow and Praat (1997) found that apple canopies in NZ typically ranged between 10,000 and 40,000 m^3 ha^{-1} TRV, with a ca. 30% seasonal increase in TRV between bud break and harvest. Many NZ orchard spray diaries record use of 2,000 litres ha^{-1} as a dilute spray, or a concentrate equivalent of this. There is no doubt that 2,000 litre sprayer tanks have set a common point of reference for chemical mixing and calibration calculations. In theory, identification of standard reference canopies that require 2000 litres ha^{-1} would allow growers to reduce or increase application rates relative to tree sizes and so maintain equivalent spray deposits. Data from experiments by Manktelow (1998) are presented in this paper to demonstrate issues associated with use of TRV to make such adjustments. The conclusion from this research was that TRV measurements only provide a partial solution to the rate adjustment problem because they do not address density or sprayer efficiency factors.

In many situations growers make empirical spray volume adjustments between different tree canopies by shutting off nozzles and/or adjusting travel speeds to match spray plumes to canopies. Adjustment of sprayer setup in this way has been encouraged in Australasian grower training programmes.

Vine Row Volume and, subsequently, Unit Canopy Row (UCR) concepts were developed and extended to Australian grape growers by Furness *et al.* (1998). Failure by grape growers to adjust to canopy area variations introduced by different row spacings has been seen as a major source of variation in deposits between canopies (Manktelow and Praat 2000). A positive feature of the UCR technique is the adjustment of application rate requirements on the basis of crop row length rather than ground area planted (Furness and Magarey 2000).

Recommendations for hectare-based chemical rates or water volumes no longer appear on Australian labels of agrochemicals for grapes. Growers are expected to calculate chemical application rate requirements on the basis of field assessments of runoff volumes, or from pictograms showing indicative application volumes (in litres per 100 metres of row length or litres per hectare) for sprawled or contained (VSP) canopy forms (Radunz 2000).

Deposit variability issues

There is a high degree of variability inherent in spray dose and coverage within different crop canopies. Deposit variability in dwarf and semi-dwarf apple canopies was documented by Cross *et al.* (1997, 2001). Similar patterns of within-canopy variability have been documented on NZ apples (Manktelow 1998) and winegrapes (Manktelow and Praat 2000). Deposit variability caused by crop canopy features, (e.g. between the inner and outer canopy, or between leaf surfaces), will have occurred during chemical testing and registration trials. This implies that some degree of within-canopy deposit variability can be ignored. However, the variability that occurred during the chemical development and registration process is generally not documented, and nor are quantitative descriptors of the canopies used. Deposit variability introduced by sprayer types and methods of operation are still not well understood or recognised by growers, despite recent emphasis on promoting deposit optimisation though progressive adjustments to spray plume direction and air outputs in order to minimise visual coverage differences between the outer and inner canopy.

Variations in mean deposits *between* canopies are driven mainly by selection and definition of chemical application rates, and by sprayer setup and operation. Both of these factors are controlled by the sprayer operator and are potentially more significant than within-canopy variability. Unfortunately the literature on spray deposits achieved from application experiments is not usually expressed in a way that allows comparison of deposits achieved between canopies in different experiments. Such comparisons are a necessary part of estimating potential to use rate standardization schemes in crops or canopies that differ from those they were developed in.

The standard deposit theory used by Holland *et al.* (1996) to develop harvest fruit residue prediction models for kiwifruit, apples and persimmons is based on observation that these canopies (with a typical LAI of around 3 in NZ) will receive average deposits of approximately 2 µg cm^{-1} when sprayed at a rate of one kilogram of active ingredient per hectare. Interestingly, data presented by Weisser and Koch (2002, Figure 3) on deposits in apples treated on the basis of fruit wall rather than ground areas, predicted deposits of 2 µg cm^{-2} if one kilogram of chemical was applied per hectare of fruit wall area.

Spray application experiments in citrus, apples and winegrapes are described below to highlight issues of deposit variability between canopies or sprayers that were raised in the preceding discussion.

Materials and Methods

1: Tree size and application volume interactions on citrus

Three citrus canopies of different sizes were sprayed on a commercial orchard in Gisborne NZ in February 2003 (Table 1). All were relatively dense, with a defined outer layer of foliage and fruit and a sparse canopy interior. No attempt was made to quantify LAI for these canopies. Each canopy was treated with a vertical boom sprayer, with nine evenly spaced Massotti gun nozzles used on each canopy. The sprayer was non air-assisted. The top three nozzles were on a hinged boom section that was set at 45^o from vertical for the medium and large canopies, with the top nozzles about 4 m from the ground. The hinged boom was lowered to 90^o for the small canopy with nozzles facing downwards at 3m from the ground. A constant travel speed of 4.2 km hr^{-1} was used for all applications, with sprayer output varied by adjusting pressure and nozzle tips, with equal outputs from all nozzles at each application volume. Application volume treatments applied to all three canopies were 1,100, 1,900 and 3,100 litres ha^{-1}.

Table 1: *Citrus canopy details*

Details	**Small canopy**	**Medium canopy**	**Large canopy**
Cultivar	Satsuma mandarin	Navel orange	Valencia orange
Height × spread (m)	2.0 × 2.8	3.2 m × 3.1	4.0 × 3.9
Canopy volume (m^3ha^{-1})	11,000	20,000	31,000
Row spacing (m)	5.0	5.0	5.0
Mean area per leaf (cm^2)	19	48	51
Mean area per fruit (cm^2)	55	104	74

A single tank mix of Tartrazine food dye at 1.25 g $litre^{-1}$ plus a non-ionic surfactant (Citowett, BASF) at 0.20 ml $litre^{-1}$ was used to apply all treatments, with each treatment made to both sides of a 50 m length of representative canopy row. Once deposits had dried, samples of six bulked leaves or fruit were picked into resealable plastic bags from the inner and outer canopy at three heights from each canopy, with sample replicates taken from three trees per treatment. Dye was recovered from samples by washing in the sample bags with 50 ml of distilled water and samples were filtered prior to quantification by absorbance on a spectrophotometer (Shimadzu) at 430 nm wavelength. Leaf areas were measured using an electronic leaf area meter (Licor) and expressed as the projected area of a single surface only. Fruit surface areas were estimated using the relationship, $4\pi r^2$, where the average from caliper measurement of the largest and smallest diameter of each fruit was used to establish the radius. Deposits were standardized in relation to actual tartrazine application rate measured from tank samples and then expressed either as volume of spray liquid deposited per tissue area, or on the basis of dye deposit standardised to an application rate of 1 kg ai ha^{-1}. Deposit data were normalised using a log transformation and deposits were compared using analysis of variance.

2: Dose management in apples on the basis of canopy factors

Seven Gala apple canopies, representing the range of tree forms encountered in NZ orchards were described and spraying treatments made immediately after harvest, between April 11-21 1995 (Table 2, canopies 1-7). LAI was estimated by counting all leaves on three trees from each block, and measuring the area of every 50th leaf on an electronic area meter. LAD was estimated by multiplying LAI × estimated tree volume.

Table 2: *Apple canopy details and descriptors*

Canopy	**Spacing** m	**Height** m	**TRV** m^3 ha^{-1}	**LAI**	**LAD**	**Volume** l ha^{-1}	**Deposit**^{y} µg cm^{-1}
1 Ebro Espalier	3.7×2.5	4	11,900	2.4	2.4	220	2.1b
						1100	1.9b
2 Slender spindle	4.0×2.0	3.5	12,000	1.7	3.1	220	3.8a
						1100	3.2a
3 Slender pyramid	5.0×2.5	5	25,000	3.4	2.2	460	2.0bc
						2300	1.9bc
4 Multi-leader	6.6×6.6	5	25,800	1.9	1.4	500	2.2b
						2500	2.0b
5 Slender pyramid	4.5×2.5	5.6	26,300	4.0	1.8	540	1.6c
						2700	1.7c
6 Hedgerow	4.6×2.0	5.5	31,400	3.0	1.2	600	1.5c
						3000	1.5d
7 Centre leader	5.3×3.9	6	33,800	3.5	1.6	620	2.3d
						3100	1.7c
Variety							
8 Royal Gala^z	5.0×2.5	5	25,000	3.4	2.2	400	3.0a
9 Standard Gala	5.0×3.0	5.3	23,000	-	-	400	1.9c
10 Fuji	5.0×3.0	5.5	23,300	-	-	400	2.2c
11 Braeburn	4.5×2.5	4.6	19,200	-	-	400	2.3b
12 Granny Smith	5.0×3.0	4.5	16,800	-	-	400	1.9c

^{y}Deposits relate to application standardised to 1 kg ai ha^{-}1. Numbers within a column followed by the same letter were not significantly different ($P<0.05$). Canopies 1-7 and 8-12 were separate experiments.
^{z}The same canopy as #3, but a different application treatment.

A second experiment was conducted in May 1995, prior to significant leaf fall, to compare cultivar effects on spray deposits in five slender pyramid trained canopies (Table 2, canopies 8-12). All were sprayed using an air blast sprayer with an 820 mm diameter axial fan with no straightening vanes, that produced 37,000 m^3 hr^{-1} at 47 m s^{-1} at the nozzles. Data are presented for dilute applications at incipient runoff volumes for canopies 1-7, and for concentrate applications (4X or 5X) based on the incipient runoff volumes for all 12 canopies. All applications were made at 3.8 km hr^{-1}, with ca. 66% of the hollow cone nozzle spray output directed into the top half of each canopy. Deposits were assessed from wash-off recovery of Brilliant Blue food dye (Bayer) applied at 1 kg ha^{-1}. Bulked samples of six leaves were collected from between 10 and 15 sample zones per canopy, representative of the inner and outer canopy in 0-1.5, 1.5-3.0 and 3.0-4.5 m heights. Deposit data were normalised using a log transformation and deposits were compared using analysis of variance. Full canopy and treatment details can be found in Manktelow (1998).

3: Canopy and sprayer interactions on wine grapes

Two separate experiments to assess sprayer effects on winegrape spray deposits are described. The first was undertaken on a commercial, cool climate, vertical shoot positioned (VSP) Cabernet Franc canopy in Hawkes Bay NZ. Treatments were applied in January 2000 after bunch closure (berries touching). This canopy was planted on 2.5 m row spacings and side and top trimmed to give a foliage wall 1.3 m in height, with an average thickness of 0.35 m in the main foliage wall and a narrower, leaf plucked, bunch zone. Average leaf layer number was 2.2, indicative of an LAI of ca. 1.3. The second experiment was conducted on a machine-pruned sprawl Cabernet Sauvignon canopy in the Clare Valley, Australia in March 2002 (preharvest). Vines were planted on 3.0 m row spacings, with a canopy wall height of 2.3 m and spread of 2.2 m, giving a vine row volume of ca. 18,000 m^3ha^{-1} or 500 m^3100 m^{-1}. The canopy had an average leaf layer number of 3.8, indicative of an LAI of ca. 1.6. Leaf layer numbers in each canopy were determined by averaging leaf contacts with a thin rod inserted horizontally through the canopy following 50 insertions at 10 cm intervals along horizontal transects at three heights.

Five spray application treatments were made to each canopy (Table 3), with deposits quantified by wash-off recovery of Brilliant Blue or Tartrazine food dyes from bulked samples of bunches from the inner and outer canopy, and leaf samples from inner and outer canopy drawn from three height zones. Prior to the deposit tests, coverage from all sprayers was checked using water sensitive papers and the sprayers adjusted to maximise coverage and evenness of deposition.

Table 3: *Winegrape canopy details and descriptors*

	Sprayer	**Configuration (per row side)**	**Output angle**	**Speed** km hr^{-1}	**Volume** l ha^{-1}
New Zealand experiment					
1	Air shear	Six nozzle vertical boom	Forward 15°	7.5	350
2	Air shear	Six nozzle vertical boom	Back 15°	7.5	350
3	Air shear	Six nozzle vertical boom	Forward 15°	7.5	1000
4	Guns (no air)	Five nozzle vertical boom	90° to canopy	6.8	1100
5	Handgun	Handgun	90° to canopy	-	1100
Australian experiment					
6	Air shear	4 fingers high, cannon low	Back 15°	6	500
7	Directed axial fan	Two fans high and low	90° to canopy	6	500
8	Directed axial fan	Two fans high and low	90° to canopy	6	1100
9	Air shear	4 fingers high and low	Back 15°	6	500
10	Air shear	Eight nozzle vertical boom	Forward/back 15°	6	500

Results

1: Tree size and application volume interactions on citrus

There were significant ($P<0.05$) within-canopy and between-canopy effects of application volume on spray deposits (μg cm^{-2}) in the citrus trees. Leaf deposits decreased with increasing tree size, and deposits on the largest canopy were less than half those on the smallest (Figure 1).

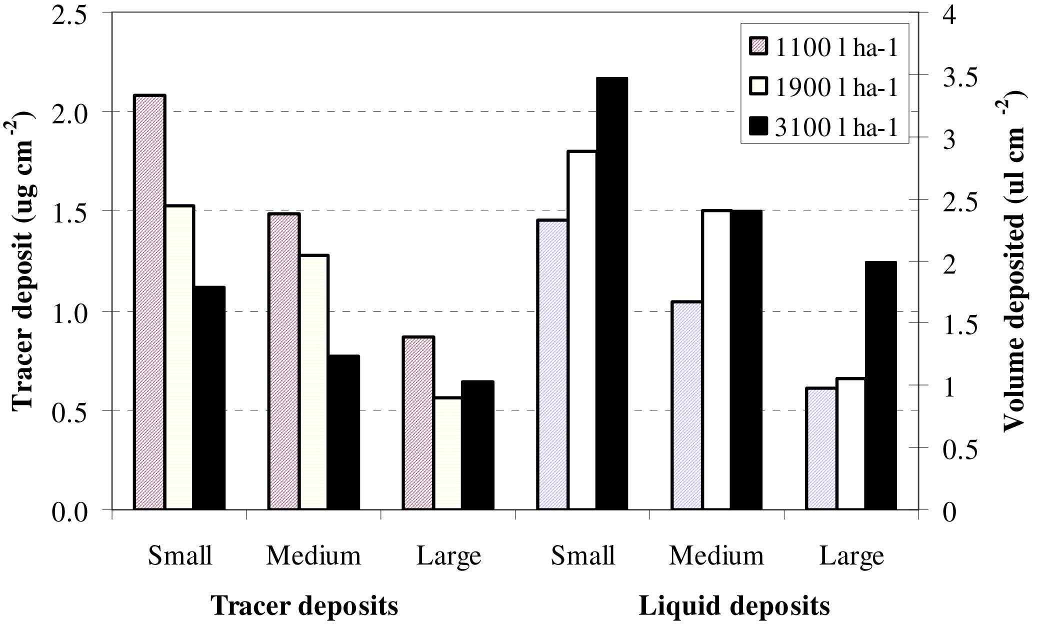

Fig. 1. Average leaf deposits on three sizes of citrus canopy from three application volumes. Deposits are shown as tracer deposits for an application equivalent to 1 kg ha^{-1} and as a volume of spray liquid deposited at each volume.

Spray volume deposits per unit area of foliage tended to increase with increasing application volumes in all canopies, however the additional deposits achieved represented a decreasing proportion of the additional volume applied. When deposits were expressed in terms of the expected chemical deposits per unit area had 1 kg ha^{-1} of chemical been applied at each volume, deposits tended to decrease with increasing spray volumes (Figure 1). Deposits to the inner canopy relative to the outer canopy increased from 30% to 49% to 66% as the application volume was increased from the small to medium to large canopies.

Deposits on fruit followed the same trend as leaf deposits, but were lower, and more variable between canopies, than the leaf deposits. Average fruit deposits across all three volumes were 54%, 73% and 82% of the leaf deposits on the small, medium and large canopies respectively.

2: Dose management in apples on the basis of canopy factors

Overall mean leaf deposit from 19 applications to 11 apple canopies was 2.1 μg cm^{-2} per 1 kg ha^{-1} of chemical applied, but with significant differences ($P<0.05$) in deposits between canopies and due to application volume (Table 2). Deposits from concentrate applications were 12% higher than those at dilute volumes (canopies 1 to 7).

TRV estimates were positively correlated with tree height (r^2 0.85) and tree volumes (r^2 0.82), and negatively correlated with LAD (r^2 0.7), but were poorly correlated with LAI (r^2 0.38). The correlation between spray deposits and TRV was very weak (r^2 0.23) and was improved (r^2 0.48) when outlying data from the Ebro Espalier (canopy 1) were excluded.

3: Canopy and sprayer interactions on wine grapes

The Australian winegrape canopy was ten-fold greater in canopy volume than the NZ canopy, although estimated leaf layer numbers and LAI differed between them by less than a factor of two. Average leaf deposits from the best treatments in each canopy were comparable, but greater within- and between-canopy variations were apparent in the bunch deposits (Table 4).

Table 4. *Tracer deposits on New Zealand and Australian winegrape canopies following 10 separate applications at 1 kg ha^{-1}*

	Bunch deposits			**Foliar deposits**		
	µg g^{-1} fresh weight			µg cm^{-2}		
Trt	**Inner**	**Outer**	**Mean^z**	**Inner**	**Outer**	**Mean^z**
New Zealand VSP canopy						
1	-	-	3.6 b	2.8	4.5	3.7 a
2	-	-	2.8 c	2.2	4.1	3.2 a
3	-	-	5.7 a	3.6	3.5	3.5 a
4	-	-	5.1 a	2.7	3.5	3.1 a
5	-	-	2.6 c	2.6	4.5	3.6 a
Average			*4.0*	*2.8*	*4.0*	*3.4*
Australian Sprawl canopy						
6	0.7	0.8	0.7 a	1.4	1.9	1.6 a
7	0.6	1.3	1.0 a	1.3	2.3	1.8 a
8	2.7	4.0	3.3 c	2.9	3.2	3.1 b
9	1.4	3.0	2.2 bc	2.3	4.1	3.2 b
10	1.5	1.8	1.6 ab	3.3	4.5	3.9 b
Average	*1.4*	*2.2*	*1.8*	*2.2*	*3.2*	*2.7*

^{z} Means with same letters in columns for each canopy were not significantly different ($P<0.05$)

Discussion

1: Tree size and application volume interactions on citrus

The trend for larger trees to receive lower deposits per unit of leaf or fruit area is entirely consistent with the concept that a spray plume has to be distributed over an increasing canopy area. It argues for the need to adjust application rates to reflect canopy area in order to achieve equivalent chemical doses between different canopies. However, the diminishing increase in deposits with increasing application volumes illustrated the potential inefficiencies caused by losses to runoff and argues against use of excessive volumes in spray applications. Application to "the point of runoff" is well established spraying jargon, but the actual volumes required to achieve this are affected by multiple variables including droplet size, air assistance, surfactants and canopy surface characteristics. Over 80% of spray application volumes recorded in a survey of citrus grower spray diaries in New Zealand indicate use of application volumes of 2000 l ha^{-1} or less (Manktelow unpublished). In Australia many citrus growers use application volumes in excess of 8,000 l/ha for most applications. The use of higher application volumes in Australia can be attributed in part to needing to fully wet inner canopy wood with oil sprays for control of some insect pests. However, the industries appear to have established different baselines for accepted practices and both would benefit from an objective method to confirm the appropriateness and efficiency of application rates in relation to chemical dosage achieved.

2: Dose management in apples on the basis of canopy factors

The leaf deposits observed in this experiment approximated the dose anticipated based on standard deposit theory (2 µg cm^{-2} per 1 kg ai ha^{-1} applied). The expected trend for increased deposits with decreased volumes was maintained, indicative of chemical wastage during higher volume applications.

TRV estimates provided a partial predictor for application volume requirements, but did not appear to apply to a highly structured canopy such as the Ebro Espalier, where foliage was arranged in dense tiers. Byers *et al.* (1989) made similar observations for an apple canopy with a dense T-trellis training system, and the same issue arose on the narrow hedgerow (VSP) versus sprawled winegrape canopies (Table 4). Under a default industry standard of 2,000 litres ha^{-1} to slender pyramid canopies (TRV ca. 20,000 m^{3}ha^{-1}), smaller trees were expected to be over-dosed and larger trees under-dosed. Simulated application rate adjustments on the basis of TRV, or other correlated descriptors, would be expected to partially reduce dose variability, but with a reversed deposit trend with canopy size (Manktelow 1998). Further, rate adjustment based on TRV does not account for effects of canopy structure on capture of spray plumes.

3: Canopy and sprayer interactions on winegrapes

Foliar deposits on the NZ winegrape canopy were highly consistent regardless of sprayer type. Variation between inner and outer canopy leaf deposits tended to reduce with increasing application volume, presumably as the outer canopy became saturated and runoff occurred. The variations between sprayers in the Australian experiment were consistent with other field experience, in which it has proven difficult to configure outputs from some sprayers to match particular target canopies. Visual assessment of sprayer performance, based on water sensitive papers, was a good predictor of the deposits measured on leaves. However, the poor bunch performance of treatment 10 would not have been predicted from the excellent water sensitive paper coverage and leaf deposits. This highlights a problem with dose prediction based on canopy volume, wall area or similar parameters. Complex structures, such as grape bunches, vary markedly between cultivars and growth stages. They project a relatively small external surface area in proportion to total surface area. The use of bunch fresh weight to express bunch spray deposits does not facilitate reliable between-canopy deposit comparisons. Variations in bunch deposits as a function of bunch position, bunch architecture, and sprayer interaction with these, need somehow to be included in dose adjustment recommendations.

Average foliar deposits between canopies were within 25% of each other, and were similar to the differences in estimated LAI for each. This similarity would not have been predicted from a canopy volume-based assessment of canopy dose requirements. The UCR concept, which was developed on Australian sprawl canopies, was introduced to New Zealand growers at the 1997 national industry conference (Miller 1997). Application volume requirements for VSP canopies were assumed to be a direct *pro-rata* of those required for sprawl canopies, and recommendations were made for dilute spray applications at no more than 300 l ha^{-1} per metre of canopy wall height. The UCR discussion came to NZ at a time when growers were adopting improved vertical boom air assisted sprayers that were capable of delivering excellent coverage at low application volumes. Many growers equated good coverage with effective dose and attempted to use the newly suggested rate recommendations, with generally poor results and uncertainty as to what volume and chemical rates were actually required. UCR recommendations in Australia now differentiate between sprawl and VSP canopies, with two-fold to four-fold variation in volumes recommended per UCR on VSP than sprawl canopies at different growth stages. Based on current Australian recommendations to industry (Radunz 2000), the canopies described in Table 4 should have required something between 1,000-1,500 and 2,000-3,000 litres ha^{-1} (or concentrate equivalent) to achieve equivalent deposits. Our results do not support these recommendations and an improved, or alternative system is required.

Relating deposits to biological dose requirement

Complex interactions between dosage, coverage, within-canopy deposit variability, chemical mode of action and pest or disease pressure and susceptibility make it impractical to reliably prescribe agrochemical doses required to achieve control for all situations. However, published bioassay dose-response data can serve as a useful tool from which to assess the potential effectiveness of different spray application treatments and to help define application requirements in different canopies. For example, Warren *et al.* (1997) identified that an effective dose (ED_{90}) of 1.7 µg cm^{-2} was required for powdery mildew (*Uncinula necator*) control with sulphur fungicides on grapevine foliage in Australia, with reliable field control obtained at ca. 2.3 µg cm^{-2} on a single leaf surface. If an equal dose were achieved on both leaf surfaces, an average sulphur dose of at least 4.6 µg cm^{-2} would be needed to achieve control. To achieve this on the inner canopy of the vines examined, sulphur application rates of 1.6 or 2.5 kg ha^{-1} would have been required on average in the VSP and sprawl canopies respectively. However the treatment that gave the lowest inner canopy leaf deposits would have required a sulphur rate of at least 3.5 kg ha^{-1} to achieve the target dose. In practice, deposits between leaf surfaces can be expected to show significant variability (Manktelow and Praat 2000), so higher sulphur rates would likely be required. Until a field tool can be developed for rapid assessment of dose, growers will depend on robust application rate recommendations, plus subjective assessments of dose from visible coverage.

Deposit variability sources and trends

Both the volume of spray liquid deposited and plant surface coverage tend to increase with increasing application volume. However, coverage is also affected by the droplet sizes in the spray plume, the presence and form of air assistance and of the surface spreading properties of the spray mixture. All of which can be manipulated independently of the application volume.

Deposit variability between outer and inner portions of a canopy tends to reduce with increasing application volume, especially when outer parts of the canopy are wetted beyond the point of runoff, with associated reductions in spray efficiency. Deposit variability will tend to increase with increasing canopy size.

If chemical application rate is held constant and application volume is adjusted, highest overall deposits will be achieved at low volumes at which runoff losses are minimised. Deposits per surface area can be expected to increase by 10-20% when application volumes are reduced by a factor of 3X or more from the volume at which dripping is first observed in the outer canopy. Under current Australian labelling recommendations growers are expected to adjust chemical application rates in proportion to runoff volumes established for different canopies and growth stages. Unfortunately perceptions of when runoff occurs differ widely between growers and application techniques and this approach has probably not served to reduce deposit variability.

Predicting and standardising deposits

It is necessary to have some understanding of the inevitable deposit variability between the inner and outer canopy versus unacceptable/avoidable variability introduced by the method of application. The first has been accounted for during agrochemical testing and registration. The second can be manipulated by the sprayer operator to enhance spray application efficiency. There is a need to identify reference canopies and be able to relate agrochemical label rate recommendations to these. This requires some knowledge of expected and required dose levels, and confirmation that these occur. While researchers have the tools to confirm deposits, sprayer operators have to take a leap of faith that dose has been achieved.

If dose rate adjustments are to be successful, the systems by which growers are to identify canopy differences and then make the requisite dose adjustments need to be simple, rapid and of proven effectiveness. Most schemes for adjusting rates present large ranges that growers need to select from, and understanding the variables that affect coverage will be critical to the future success and uptake of dose adjustment schemes. Growers need better methods for quantifying deposits so that rate adjustment, whether based on label recommendations, canopy size, leaf area, target surfaces, machinery efficiency, or disease pressure, lead to a closer approximation of the required dose.

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