DRIFT FROM ORCHARD SPRAYING

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ABSTRACT

Research from 1989 to 1996 into drift from air blast orchard spraying, principally in kiwifruit blocks with live shelter, is reviewed. A mass balance study showed 96% of applied vinclozolin could be accounted for with 75% on the target crop, 19% on the ground or shelter and about 2% leaving the block as drift. Summarising results from 21 trials gave trends for both deposited and aerial drift outside the shelter to decrease exponentially with distance (distance for 50% decline, $d_{0.5}$, ca. 26 m). Chlorpyrifos, pirimiphos-methyl and particularly diazinon gave elevated drift levels that persisted after spraying ceased. This was attributed to volatilisation from the crop. Typical drift levels for a range of pesticides were 0.5-5 mg/m³ in air samples and 20-200 mg/m² in deposits 50 m downwind of shelter. Air measurements in urban areas 0.5-1 km from orchards detected low levels of chlorpyrifos and diazinon (5-40 ng/m³). Drift levels were not strongly influenced by formulation, water rate (500-2150 litres/ha) or wind speed (0.5-5 m/sec). Risks to human health from drift outside sprayed blocks were assessed as minimal.

Keywords: spray drift, kiwifruit, pesticides residues, pesticide volatility

INTRODUCTION

Concern over drift from spraying has increased in orcharding districts over recent years as growing urban communities come into closer contact with intensified horticultural production. Published information on spray drift from orcharding is limited, particularly under New Zealand conditions where horticultural blocks are often surrounded by shelter belts which may be expected to attenuate drift. The Parliamentary Commissioner for the Environment has reviewed the general area of spray drift and made recommendations regarding legislation, sector responsibilities and further research needs (P.C.E. 1993). The Ministry of Health has recently developed guidelines for the investigation and surveillance of spray drift incidents (Begg and Bates 1996). In 1989 the kiwifruit industry identified drift as an issue where it had responsibilities. Funding was provided over six years for research and the results have been presented to industry as comprehensive reports and articles (Holland and Maber 1991; 1992; Holland *et al.* 1994).

This review summarises results from a wide range of field trials and measurements on spray drift from orchards, principally carried out in kiwifruit. The methodology for drift measurement and the factors influencing drift are discussed and some human health risk assessments are made based on the measured levels of pesticides in deposits and air.

METHODS

Trial Sites

All measurements were made on standard orchard blocks in the Waikato and Bay of Plenty during the main growing season (December-June). The 21 trials covered a period from 1989-1996. The principal crop studied was kiwifruit grown on T bars but two trials were carried out on persimmons. Sprayed blocks were 0.35-0.65 ha in area and surrounded by live, mature shelter, usually 8-10 m high *Salix* (*matsudana* cultivars) or *Casurina* spp.

Pesticides and spray application

Spray applications were by standard axial fan assisted hydraulic sprayers calibrated to deliver volume rates in the range 500-2250 litres/ha. The pesticides studied included chlorpyrifos, diazinon, iprodione, pirimiphos-methyl and vinclozolin at either half or full label rates (0.5-1.0 kg/ha). In some trials two sprayers were operated in tandem in the same or adjacent blocks applying different chemicals to assess variables such as water rate.

Mass balance study

An application of vinclozolin (0.71 kg/ha) was made to a kiwifruit block (0.7 ha). In addition to monitoring of downwind drift, intensive sampling was undertaken inside the block covering regions including crop leaves, canes, fruit and support structures, ground and shelter. At least 5 samples were taken from each region.

Spray Drift Logger (SDL) system

Measurements on drift and associated meteorological information were centred around a specially constructed sequential sampler system mounted on a trailer with a retractable mast. Air samplers (operated at high volume) and filter papers were mounted as pairs in two banks of six. Mechanical valves and flaps enabled the pairs of samplers to be sequentially exposed for various periods. The banks of samplers were mounted on the mast 2 m above ground level. Wind speed and wind direction sensors were mounted at 10 m, with temperature sensors at 10 and 2 m and a relative humidity sensor at 2 m. The meteorological information was logged automatically into a portable computer which also controlled the sampling sequences.

Sampling

Samplers were laid out prior to spray application, generally at distances from the downwind shelter. Some sampling was also undertaken inside sprayed blocks. Leaf punch samples were used to assess deposits within the crop, on shelter and on other foliage. Fifty 2 cm diameter leaf disks were taken for each sample and immersed in hexane for 16 hours. Glass beakers (500 ml, 11.5 cm diameter) were used to collect samples of deposited spray. Clean beakers were placed on the ground and immediately following the sampling period they were rinsed with 3 x 15 ml acetone. Filter papers (9 cm diam, glass fibre GFA or cellulose #1) were also used to collect deposited drift. After the sampling period each filter was placed into a glass tube with acetone. Aerial drift (aerosols and vapour) was trapped using suction air filters packed with XAD-4 polystyrene resin beads (Woodrow and Seiber 1978). The samplers consisted of a 47 mm i.d. aluminium tube and funnel packed with a 10 mm layer of prewashed resin (20-60 mesh) held between stainless steel mesh support disks. These were mounted horizontally and operated at air flows of 140 litres/min (high volume) or 21-24 litres/min (low volume). Immediately following the sampling period, the filters were disassembled and the resin transferred to tubes along with acetone washings of the tube, funnel and mesh assemblies.

Pesticide Analysis

Solvent extracts were concentrated to low volume and analysed by capillary gas chromatography with splitless injection onto a 30 m x 0.20 mm i.d. HP5 column and detection by electron capture (vinclozolin, iprodione) or nitrogen phosphorus (organophosphorus insecticides). The results were expressed per unit area ($\mu\text{g}/\text{m}^2$) for deposited drift and per unit volume ($\mu\text{g}/\text{m}^3$) for aerial drift (aerosols plus true vapour).

RESULTS AND DISCUSSION

Sampling techniques

The sampling systems were shown by control and spiking experiments to give low blanks and high recoveries for the test pesticides (>90% recovery for beakers or filter papers; >75% recovery for air samplers). In field tests, deposits were similar whether captured by beaker or filter paper and detection limits were 2-5 $\mu\text{g}/\text{m}^2$. Air sampling at low or high volume air flows gave comparable air concentrations. Thus deviations from isokinetic sampling conditions (sampling air speed at front of assembly matching the wind speed) were not sufficient to change the sampling efficiency within the range of wind speeds and airflows tested. The detection limits were *ca* 0.005 $\mu\text{g}/\text{m}^3$ (high volume sampling, 1 h) to 0.2 $\mu\text{g}/\text{m}^3$ (low volume sampling, 10 min). Vinclozolin proved to be

a very useful pesticide for drift measurements. It is of low toxicity, stable, of low volatility and readily measured with high sensitivity by GC-ECD.

Mass balance trial

The measured deposits within the treated block and drift outside the block are summarised in Table 1. These values were converted to percentages of the applied dose of vinclozolin (0.5 kg) using total area estimates for the various regions of the orchard. A leaf area index of 3.0 was taken for the kiwifruit canopy (Smith and Buwalda 1994), and 2.0 for the shelter. The estimates for quantities of drift outside the block are based on the crude assumptions that deposited drift declined exponentially with distance from shelter ($d_{0.5} = 26$ m) and that aerial drift was contained in a 150 m wide by 25 m high air column for the duration of spraying (30 min) at the mean concentration measured.

All the applied vinclozolin was accounted for within the errors of the measurements. The target crop received 75% of the spray, 19% was on ground or shelter and about 2% left the block in the form of drift. The rapid decrease in ground deposited drift is noteworthy with reductions of 10-20 fold to the inside edge of the block (the shelter was not sprayed) and by a further factor of 500 at 50 m downwind of the shelter. These are more favourable spray recovery and drift attenuation characteristics than reported for unsheltered apple orchards (MacCollum *et al.* 1986).

TABLE 1: Mass balance for application of vinclozolin applied to kiwifruit by airblast sprayer (0.71 kg/ha applied in 1420 litres water). Windspeed: 1 m/sec at 10 m height.

	Measured deposit $\mu\text{g}/\text{cm}^2$	Estimated recovery % of applied
Kiwifruit canopy (leaf punches, random)	2.9 ± 0.4	71.1
Fruit (whole fruit)	1.5 ± 0.2	2.0
Trunk, canes (sections)	1.4 ± 0.2	1.3
Support posts (filter papers)		0.6
30 cm height	0.5 ± 0.4	
120 cm height	1.1 ± 0.6	
Ground inside block (beakers)		
under canopy	0.4 ± 0.24	16.0
edge of canopy	1.1 ± 0.6	
tractor row	1.7 ± 0.7	
against shelter	0.15 ± 0.1	
Shelter (filter papers)		2.8
2 m height	0.24 ± 0.1	
4 m height	0.15 ± 0.1	
Ground 50 m downwind of shelter (beakers)	$3.3 \pm 0.5 \mu\text{g}/\text{m}^2$	0.3
Air 50 m downwind (air samplers, 2 m height)	$1.1 \pm 0.2 \mu\text{g}/\text{m}^3$	1.5
TOTAL		95.6%

Timeframe of drift

The SDL system was used to follow drift from applications of vinclozolin/diazinon or vinclozolin/pirimiphos-methyl mixtures. Fig. 1 illustrates a typical pattern of data for sequential air sampling 36 m downwind of shelter prior to, during and after spray application. The residues for relatively involatile vinclozolin peaked during spraying and then declined to negligible levels. However the levels of volatile diazinon were much higher and also remained high after spraying stopped. Similar, but less exaggerated patterns were found for chlorpyrifos and pirimiphos-methyl which also have significant volatility. For these pesticides the air samplers are collecting not only aerosol and vapour drift from the spray, but also pesticide volatilising off deposits on the crop and ground surfaces.

Interestingly, deposited drift samplers also collected residues of volatile pesticides well after cessation of spraying, indicating that the filter papers have some affinity for low levels of pesticide vapour. Other studies on drift from orchard spraying have measured continuing evolution of volatile pesticides for several days after application (Woodrow *et al.* 1977; Glotfelty *et al.* 1990; Woodrow *et al.* 1997).

FIGURE 1: Aerial drift from ground spraying of kiwifruit with vinclozolin (0.5 kg/ha) and diazinon (1.0 kg/ha). Windspeed 5m/sec at 5 m height. Monitoring at 2 m height, 36m downwind of boundary shelter.

Factors influencing levels of drift beyond the shelter

Figs. 2 and 3 summarise the relationship between sampling distance and the drift measured in aerial and deposit collectors respectively from over 21 ground spraying events in the period 1991 to 1996. The drift data was normalised for application rate (1 kg/ha, aerial) or quantity (1 kg, deposits). Most data were collected with the SDL system positioned 30–50 m downwind of the boundary shelter. The correlation coefficients are poor but the trend lines are consistent with slopes indicating a halving of drift levels for each 26 m distance from the shelter. The variations in levels at each distance reflect the wide variety of conditions studied including pesticide type, windspeed, shelter density, temperature and humidity. In addition, drift patterns were not consistent close to the shelter and measured drift at less than 25 m was frequently lower than expected. As indicated above, the pesticide properties have a major influence on drift levels. For example extracting data for the nine trials with diazinon improved the R value for aerial drift/distance to 0.8 and on a single trial basis, the R values were generally greater than 0.95 (closest sampler 25 m).

Comparisons between trials, including some with dual sprayers to minimise inter-run climatic effects, allowed the following broad conclusions to be drawn:

1. Formulation (EC, WP, FL, presence of mineral oil) has no significant effect on drift.
2. Drift levels are similar for high or low water rates applied with well calibrated sprayers (2150 to 500 litres/ha).
3. Drift levels increase with wind speed, particularly above 5 m/sec, but the effects in the range 1–5 m/sec are not marked. Presumably the greater quantities of drift undergo more dilution at higher wind speeds.
4. Density of shelter has a marked effect with live shelter filtering more drift than artificial wind break. However, openings in the lower canopy of mature live shelter can let drift through. Shelter is unlikely to greatly influence levels of true vapour drift

at more than 20 m downwind.

Drift to urban areas

Drift measurements were made in Katikati during March/April 1995 during a period of intensive spraying in the surrounding district. Sequential air samples (1-4 hour each)

FIGURE 2: Aerial drift beyond the boundary shelter for ground sprayed kiwifruit. Summary of 21 trials 1991 - 1996. Drift values adjusted to a standard application rate of 1 kg a.i./ha. $R = 0.57$

FIGURE 3: Deposited drift beyond the boundary shelter for ground sprayed kiwifruit. Summary of 21 trials 1991 - 1996. Drift values adjusted to a standard application of 1 kg a.i. $R = 0.52$

were taken over 20 hour periods at stations 0.5-1 km distant from kiwifruit orchards. During known applications of chlorpyrifos, low levels were detected (0.005 - $0.040 \mu\text{g}/\text{m}^3$) and these persisted after spraying had ceased. About 20% of air samples contained diazinon at the detection limit (0.003 - $0.030 \mu\text{g}/\text{m}^3$) although diazinon spraying was not known to have occurred during the sampling periods. These levels are consistent with exponential dilution of $1 \mu\text{g}/\text{m}^3$ levels near sprayed blocks and are similar to those measured in Californian towns close to agricultural districts (Seiber *et al.* 1989).

Risk assessment

The most appropriate comparison points for human exposure to a pesticides are the Acceptable Daily Intake (ADI). Although the ADI is principally based on minimising risks of chronic effects, the relatively high acute toxicities for organophosphorus insecticides are also incorporated into their ADIs ($\mu\text{g}/\text{kg}/\text{day}$: diazinon 2, chlorpyrifos 10, pirimiphos-methyl 30). Table 2 presents estimates of exposures to diazinon from typical drift scenarios based on the conservative assumption of complete absorption of deposits on the skin and of inhaled drift.

TABLE 2: Exposure to diazinon from spray drift (1 kg applied, 60 kg adult, upper body fully exposed).

Drift Level	2 $\mu\text{g}/\text{cm}^2$ in orchard	Dermal 100 $\mu\text{g}/\text{m}^2$ outside shelter	10 $\mu\text{g}/\text{m}^2$ 100 m	20 $\mu\text{g}/\text{m}^3$ 1 hr, in orchard	Inhalation 5 $\mu\text{g}/\text{m}^3$ 1 hr, outside shelter	0.5 $\mu\text{g}/\text{m}^3$ 24 hr, 100 m
Dose $\mu\text{g}/\text{kg}/\text{day}$	220	1.1	0.11	0.33	0.08	0.17
Ratio to ADI	110	0.55	0.055	0.17	0.041	0.08

These estimates are in the range of those presented in the interim guidelines (Begg and Bates 1996). In-orchard exposure at these maximal levels during spray application is obviously undesirable and supports all the recommendations for wearing of safety equipment. The theoretical dermal dose outside a block approaches the ADI only if the bystander is close to the shelter throughout the application. Inhalation doses are low even with the continuing volatilisation which results in potential 24 hour exposures on neighbouring properties. Exposure estimates have been developed for other more diverse scenarios such as dermal contact with drift affected foliage or contamination of drinking water (Begg and Bates 1996).

CONCLUSIONS

The high leaf area indices and boundary shelter of typical kiwifruit orchards are favourable to capture of spray and thereby minimise drift outside the orchard. This has been confirmed by the mass balance study. However measurable drift does escape sprayed blocks with levels in air or deposit being attenuated with distance from the shelter. Volatile pesticides such as diazinon rapidly evaporate from the crop and this factor makes a major contribution to aerial drift both during and after spraying events. The volatility of the pesticide and the density of boundary shelter are the main factors influencing levels of drift where well-calibrated airblast sprayers are operated in low winds (1-5 m/sec). Risks to the health of bystanders outside sprayed blocks under these conditions are minimal. These studies have contributed to the minimising spray drift through the development of the Agrichemical User's Code of Practice (NZS6409:1995) and the associated certification of spray applicators.

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