Drift measurements for two systems of hydrogen cyanamide spraying in kiwifruit

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Abstract Kiwifruit are sprayed in late winter with hydrogen cyanamide to enhance with bud burst. The trellis layout of kiwifruit vines in combination with the canopy dormancy at that time of year means that a higher portion of the spray is able to drift away from the canopy. A spray application field study was conducted in a kiwifruit orchard to investigate spray drift potential, with particular focus for conditions relevant to hydrogen cyanamide applications. Spray application with conventional airblast-sprayer hollow-cone nozzles/adjuvant was compared with air-induction (AI) nozzles/drift-reducing adjuvant. Spray was applied every second row in the orchard with spray drift sampling conducted by measuring vertical distribution of spray deposition on both sides of the downwind shelterbelt. The trial showed that airborne drift carried to a height of at least 15 m to the downwind edge of the orchard, which was the height of the vertical sampling towers. The air-induction nozzle/drift-reducing adjuvant system reduced the drift intercepted at 15 m height on the downwind side of the shelterbelt by approximately 78% compared to the standard nozzle/adjuvant system.

Keywords kiwifruit spray, hydrogen cyanamide, spray drift, airblast sprayer, air induction nozzles

INTRODUCTION

Application of bud-burst assisting chemicals to kiwifruit orchards presents a unique challenge due to the pergola trellising used to support kiwifruit vines and the status of the canopy at the time of year when these chemicals are sprayed. Standard air-blast sprayers direct spray in a mostly vertical upwards trajectory, and the bare canopy presents very little interception area. This situation results in a very low percentage of the mass applied actually landing on the plant, and a very high potential for off-target spray drift. The primary chemical used to assist bud burst is hydrogen cyanamide (CH_2N_2), which has toxicity to humans. There have been two studies of poisonings to bystanders in New Zealand due

to hydrogen cyanamide spray drift (Schep et al. 2007; Schep et al. 2009).

Due to the unique canopy structure and typical sprayer setup for kiwifruit orchards, there have been comparatively few studies of spray drift from such orchards, especially with shelterbelts, compared to the extensive literature of orchard spraying in general (Bonds et al. 2015).

One study of spray drift from kiwifruit orchards used sequential air samplers to detect pesticides and these chemicals were recorded up to 1.0 km beyond the spray site (P Holland, HortResearch, pers. comm.). In another study, Holland et al. (1997) found that approximately 2% of the applied mass of pesticide spray applied to a block left the intended area as spray drift and

landed on a shelterbelt. Gaskin et al. (2006) found that air-inclusion (AI) nozzles in combination with an adjuvant could reduce spray drift by as much as 86% compared to standard application technologies available the time. They made measurements as high as 3.3 m above the ground (1.3 m above the canopy). Gaskin et al. (2007) found that AI nozzles could reduce downwind drift by at least 70% compared to standard cone nozzles for sprays applied to dormant canes. They also noted one of the challenges in spray drift studies is that “wind speed cannot be controlled”. Gaskin et al. (2008) measured drift on 5-m tall sample poles. They found drift reductions of 60–95% with AI nozzles, though the effect was weaker at higher wind velocities. All three of these studies were conducted in orchards without shelterbelts. However, shelterbelts are a common feature in New Zealand orchards (Moller et al. 2007) so studies need to be conducted in areas with shelterbelts. It is well known that shelterbelts reduce off-target drift (Holland et al. 1997), though drift from hydrogen cyanamide spraying in a kiwifruit orchard surrounded by a shelterbelt has not previously been studied.

Kiwifruit production is undertaken on a commercial scale in Italy, Chile, the United States, and China but no publications of spray drift studies from those countries could be found. Two other related studies of interest were one on drift from spraying the shelterbelts for the control of scale insects (Gaskin et al. 2009) and the other was on the effects of canopy density on spray deposition in kiwifruit (Gaskin et al. 2013).

The purpose of this field study was to compare two common strategies for applying hydrogen cyanamide in dormant kiwifruit with the intention of comparing their relative drift potentials, and to assess the total drift out of a kiwifruit orchard that is surrounded by shelterbelts.

MATERIALS AND METHODS

The study was conducted during winter 2012 (28 August) near Te Puke, New Zealand (37°48'28"S, 176°22'15"E) when there was no foliage on the vines. The trial undertook to measure the amount

of spray drift that occurred and how much of this drift was captured by 10–12 m high north south shelterbelt of *Cryptomeria* sp. shelterbelt on the eastern side of the orchard, which was downwind of the spray application. The orchard was approximately 1.4 ha with a length of 200 m and width of 70 m.

Two treatments that the kiwifruit industry use, set up by a spray contractor, were applied using an application rate of hydrogen cyanamide (Hi-Cane®, Nufarm, Auckland New Zealand; 520 g/litre ai) in water at 600 L/ha. A Teejet 844 AB nozzle control system (Spraying Systems Company, Wheaton, Illinois) was used for both treatments. System A used Albuz TVI hollow-cone Air Induction (AI) nozzles (Albuz Spray, France), with an anionic polyacrylamide adjuvant, DriftStop (Nufarm, Auckland, New Zealand) at a rate of 0.025% vol/vol. This adjuvant is recommended for use with AI nozzles to reduce spray drift around kiwifruit at a rate of 0.05–0.25% vol/vol (Nufarm n.d.). System B used an airblast sprayer at a pressure of 15 bar and there were 10 nozzles, five on each side of the centre line. It also used traditional ceramic nozzles (Albuz 40) over the same configuration but with a higher pressure of 19 bar and the non-ionic surfactant adjuvant, Latron B-1956 (BFR Products, Five Points, California) at a rate of 0.1% vol/vol. For these conditions, the air induction nozzles will be near the ASAE Extra Coarse/Very Coarse drop size classification boundary (around 550 µm) and the traditional nozzles near the Fine/Very Fine boundary (around 150 µm). The sprayer was moved using a tractor at a speed of 6 km/h or 1.67 m/s for both treatments. Rhodamine WT dye was added as a tracer at a rate of 0.2% by volume to measure deposits. Average wind velocities were 4.7 km/h (1.3 m/s) and 4.9 km/h (1.4 m/s) during the two treatments, respectively. The top anemometer average wind direction was 240 degrees clockwise from north and the bottom anemometer 215 degrees from north.

Drift was sampled by four 15-m tall towers downwind of the spray application zone. Towers were placed in pairs, two on the inward side of the shelterbelt, 1 m from the field edge and two

immediately behind them on the outer side of the shelterbelt, within 2 m of the shelterbelt. There were four vertical sampling strings per tower, of 0.5-mm diameter monofilament nylon lines. These were connected to a 1.5-m wide horizontal bar fixed to the top of the tower, with enough space (approximately 10 cm) between the lines to prevent cross-contamination, and a pulley at the end of each bar to aid in collecting the string after each trial. The diameter of the collection strings was chosen to maximise catch efficiency of the finest far-field drops (May & Clifford 1967). All collector materials were bench tested prior to use for tracer recovery and potential leaching of contamination from the manufacturing process that may affect the fluorescent tracer measurements. A schematic diagram of the experimental setup for the shelterbelt and collection towers is shown in Figure 1, and photographs of the two collection towers in front of the shelterbelt are shown in Figure 2.

One pass that sprayed 6 rows, i.e. every second row of the 12 rows in the orchard, was made for each treatment. After being allowed to dry, and 0.5-mm monofilament strings were lowered from the pole, cut into 1-m lengths, placed in plastic bags, then stored in a dark container for 3 to 5 hours then frozen at the Lincoln Agritech Ltd. laboratory in Hamilton. The fluorescence analyses of the samples were conducted over the next few months. Tank samples also were taken

Figure 1 Cross section of kiwifruit spray field trial.

from the sprayer at the time of the trial, were stored as for the strings and were analysed with a fluorometer at the same time as the other samples

Figure 2 Drift-collecting towers in the field on the inside of the shelterbelt.

to provide base fluorometer readings so that the spray sample readings by the fluorometer could be turned into deposition using the string area. The fluorometer provides a reading of relative fluorescence units (RFU) for each sample of string, which can be converted to mass with a calibration curve.

The total measured drift was determined by integrating the vertically measured drift and comparing it with the applied mass, calculated by integrating the total width of 6 rows sprayed at 600 L/ha.

The results were analysed to show: a) that the hedge captured spray; and b) there was a difference in the measured drift between the two treatments. It was assumed that the difference in the measurements between the upwind and downwind towers would show how much drift the hedge captured. The strings were 4-mm wide over 10 m or 0.04% of the width and would capture all the spray landing on them, while the poles were 10 cm wide or 1% of the width but would only capture about 50% of what landed on them. Therefore, of the upwind towers would prevent <1% of spray reaching the hedge so would have little overall effect on the results. Means and standard deviations were used to ascertain P values between the spray readings from the upwind and downwind towers to assess the effect of the hedge while, for the treatments, the drift on the downwind towers was compared in a similar manner. Values of $P < 0.05$ were considered significant.

The analysis also involved calculation of a Bayes Factor (BF01) as another method of assessing whether the results are significant as P values give the probability that the result will be worse, i.e. if there is no effect, while Bayes

Factors directly compares whether or not the measurements show an effect.

RESULTS

The shelterbelt at the trial site was typical of well-managed, established *Cryptomeria* sp. It had dense foliage resulting in little optical porosity (Fig. 2), so would provide information on the ability of this type of shelterbelt to capture spray. The deposition onto the strings inside and outside the shelterbelt is shown in Figure 3 for both System A and B applications. The total measured drift is provided in Table 1. Spray onto the upwind tower from System A was more concentrated closer the ground, while the spray from System B exited from the orchard much higher up the upwind tower.

The analysis showed that the standard error 5% and 7% (facing/ away from the spray respectively) for System A and 12% and 19%

Figure 3 Measured spray depositions from two different nozzle/adjuvant types on 15-m tall poles on either side (upwind and downwind) of the shelterbelt.

Table 1 Measured drift integrated overall deposits (Figure 3a) to 15-m sampler height. Values averaged over all strings on both sets of towers and presented as a percentage of total applied mass.

Treatment system	Measured drift on the side of the shelterbelt facing the sprayer (%)	Measured drift on the side of the shelterbelt away from the sprayer (%)
A	2.31 +/- 0.115	0.071 +/- 0.005
B	1.72 +/- 0.211	0.323 +/- 0.063

for System B. The coefficient of variation (CV) values for all the 1-m segments for the 6 or 8 lines averaged 30% for the upwind or facing sprayer towers and 60% for the downwind of shelterbelt towers and shows the spread of the results.

The measurements show that System A significantly reduced drift when compared with standard System B. There were significant differences between the two systems for the amount of spray captured by the upwind towers ($P=0.0238$; $BF01=0.420$) compared with the downwind towers ($P=0.0013$; $BF01=0.053$). The hedge captured spray generated by each system as the upwind-tower measurements were significantly different to those from the downwind tower; $P<0.05$ and $BF01=5.03\times10^{-8}$ for System A with $P<0.05$ and $BF01=0.005$ for System B.

For System A, the shelterbelt filtered out 97% of the spray drift, while for the System B, it filtered out 81% of the spray drift. At the downwind towers, the spray mass collected for System A was 22% of that for System B, i.e. System A reduced the drift coming out of the shelterbelt by 78%. All the results showed spray mass flowing over the top of the hedge but also that there was significant mass deposition at the upmost level of the towers from 0.01 to 0.03 L/ha, so not all the drifting spray was collected.

DISCUSSION

The results obtained here meant that use of System A (AI nozzles with Driftstop adjuvant) reduced spray drift measured downwind of the hedge by 78% compared with System B using standard nozzles and adjuvant. The shelterbelt collected a greater percentage of the spray when System A was used compared with a standard spraying system (B) (Fig. 3). This result reflected the larger droplet sizes produced by System A being caught more efficiently by the shelter foliage, as would be expected by standard impaction theory, as described by May and Clifford (1967). The higher value of deposition above 11 m reflected the larger portion of spray in the driftable fraction from the application with System B. The results showed that 15-m towers were not high enough

to collect all the drift. Thus, future experiments should use higher towers.

The observation that the spray drift was above the maximum sampled height in both treatments is consistent with work of the Spray Drift Task Force in the United States (Johnson 1995). That study found spray mass flow well above the sprayed almond tree canopies and a tendency of upward moving spray clouds to continue moving upward. It is also consistent with work done by Connell et al. (2010), Raupach et al. (2000), and Peterson et al. (2008) that showed that shelterbelts tend to direct airflow and drift particles up and over it. The vertical flow of the drift is inversely related to the porosity of the shelterbelt. Denser shelterbelts capture more spray, but result in more flow over top and less movement and filtration through foliage. However, density was not varied in the current study. This previous work highlights a need for further research to improve the understanding of the vertical spray drift profile in airblast-sprayer application scenarios, especially where particles begin in a state of active upward motion as in kiwifruit spraying. This also suggests the utility of future work that observes differences in shelterbelt porosity in relation to the vertical flow and drift out of the orchard in a similar airblast/orchard system. The main conclusion from this study is that a combination of AI nozzles and Driftstop adjuvant reduces drift by 78% and that further experiments would be needed to cover different atmospheric conditions and hedges with different compositions and optical porosities to develop a robust model/decision system to measure spray drift. Such work would also be valuable for other types of spray such as insecticides or herbicides.

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