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Report to Zespri Group Ltd

Studies to determine the rainfastness of residues of commercial and organic copper sprays on dormant kiwifruit canes

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EXECUTIVE SUMMARY

Two studies were undertaken to determine (1) how rainfall affects residues of commercial copper sprays on Hort 16A and Hayward dormant canes (both old and replacement wood) and (2) how rainfall affects residues of organic copper+oil sprays on Hayward replacement canes.

The commercial sprays used were Nordox 75WG (Gro-Chem), Kocide Opti (DuPont), Liquicop (Elisio), Cuprofix (Nufarm) and Bordeaux (10.8.1000) mix. The organic sprays were Nordox 75WG plus either 1% or 2% Excel Organic oil. Spray application was made to freshly sampled canes with a moving head tracksprayer. Rain was applied at moderate-heavy intensity in varying amounts up to 100 mm. Copper residues were then recovered from cane surfaces by acid washing and analyses were undertaken by Hill Laboratories. The findings were:

Commercial copper sprays

- Copper sprays applied to kiwifruit canes are highly resistant to rain wash-off.

- After 100 mm rain, more than 75% of initial spray deposits on replacement/new canes (and probably on old canes also) was still present.

- Hayward new canes retained highest and Hayward old canes retained least copper, but generally there was little difference in performance between Hort 16A and Hayward, or old and new canes.

- Du-Wett, and similar superspreader adjuvants such as Du-Wett Rainmaster and Driftstop, can be used in concentrate sprays on canes without affecting the longevity of copper residues.

- Du-Wett, and similar superspreader adjuvants such as Du-Wett Rainmaster and Driftstop, improve the spreading and coverage of copper sprays on canes.

Organic 'oil' sprays

- Nordox copper sprays applied to organic kiwifruit canes are highly resistant to rain wash-off.

- After 100 mm rain, more than 84% of initial spray deposits on new canes were still present.

- Excel Organic oil did not improve retention of dilute copper sprays on canes, or affect the resistance of spray deposits to rain wash-off.

- Excel Organic oil had very little effect on droplet spreading on canes.

Studies to determine the rainfastness of residues of commercial and organic copper sprays on dormant kiwifruit canes

Introduction

The infection of kiwifruit by *Pseudomonas syringae pv Actinidiae* (Psa) occurs via heavy rain and strong winds. The bacterium may infect the dormant plant in winter through leaf scars, insect damage, pruning wounds on the vine, etc. Copper sprays are known to have protectant activity against Psa, but their longevity on canes was unknown.

The two studies reported here were undertaken to determine (1) how rainfall affects residues of commercial copper sprays on Hort 16A and Hayward canes (both old and replacement wood) and (2) how rainfall affects residues of organic copper+oil sprays on Hayward replacement canes.

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Preparing canes for the study in the lab…….
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STUDY 1: EFFECT OF RAINFALL ON COMMERCIAL COPPER SPRAY RESIDUES ON HORT 16A AND HAYWARD CANES

This study investigated the effect of up to 100 mm of moderately heavy rain (simulated) applied to canes which had previously had typical dilute or concentrated copper sprays applied. The aim was to confirm the residues of five commercial copper sprays retained on the canes pre-rain and their relative resistance to wash-off by rain.

Methods and Materials

Hort 16A and Hayward kiwifruit canes were freshly sampled by Zespri in June 2011, immediately prior to the trial, from blocks which had received no copper sprays in the current season. Four types of canes were sampled; replacement/new (N) and old (O) canes from both Hort 16A (G) and Hayward (H) vines. They were stored at 4°C until used, within four days of sampling. Immediately prior to spraying, lengths of cane were trimmed to 40 cm length and mounted on packing trays (Photo 1A), with 10 canes per tray (Photo 1B), secured at one end with tape. Canes were not touching, or shaded by each other.

Photo 1A: Setting up canes on trays.

Photo 1B: Hayward new (HN) canes set up on a packing tray for spraying

Treatments were as nominated by Zespri:

1. Nordox 75WG (750 g Cu, CuO WDG, Gro-Chem); 1.1 kg/600 L/ha (= 0.825 kg Cu)
2. Kocide Opti (300 g Cu, CuOH WDG, Du Pont); 1.3 kg/600 L/ha (= 0.390 kg Cu)
3. Liquicop (93 g/L Cu; Elisio); 5 L/600 L/ha (= 0.465 kg Cu)
4. Cuprofix Disperss (200 g/kg Cu, Nufarm) 2.4 kg/600 L/ha (= 0.480 kg Cu)
5. Bordeaux (10.8.1000) in 2000 L/ha (20 kg $CuSO_4$ + 16 kg $Ca(OH)_2$) (= 7.96 kg Cu)

All treatments contained tartrazine dye at 5 g/L to accurately determine spray delivery volumes. Treatments 1-5 contained 0.1% Du-Wett (Etec®). This equated to 600 ml/600 L/ha, which is almost twice the recommended rate for concentrate foliar sprays. The reason for this was that Du-Wett was mistakenly substituted for Du-Wett Rainmaster, which is routinely applied at twice the recommended Du-Wett rate. (Note that each chemical treatment was subsequently repeated in a dilute spray application without adjuvant addition to ensure that Du-Wett use did not compromise copper rainfastness on canes).

The 600 L/ha treatments were applied with two TX12 nozzles (250kpa, VMD 220, Spraying Systems Data sheet 11825-52M) mounted 50 cm apart on a boom in the PPC_{NZ} Tracksprayer. The boom was mounted 1.5 m above the target to ensure terminal velocity at droplet impact. Initially an air induction hollow cone nozzle was intended to be used, but the copper mixes frequently blocked the air induction ports. The TX12 nozzle, operated at sub-optimum pressure, produced bigger than normal droplets from this hollow cone design. Nozzle selection was discussed with and confirmed by Bill May. The 2000 L/ha treatments were applied through two twin cap nozzles (with two 8004EVS nozzles each, at 150 kPa pressure). The nozzles used in this study had a slightly larger VMD than those typically used in dilute kiwifruit sprays (350 micron, Spraying Systems Co Data sheet 37043-5M) because of the flow required to apply the 2000 L/ha treatment. The canes were sprayed with two passes to apply the 2000 L/ha, and rotated within the spray booth between passes to ensure even spray application.

All treatments were applied to five trays (containing 10 replicate canes) of each type of cane (GN, GO, HN, HO; Photo 2) and the sprayed canes were left to dry overnight. The following day, rain was applied to the dry canes at ca. 10 mm/h, which equated to a moderately heavy rain event, for varying time intervals (Photo 3). A tray of each cane type in each treatment received no rain, or a nominal 25, 50, 75 or 100 mm of total rain. Canes were left under cover for 24 h to dry. Once dry, the canes in each tray had 5 cm trimmed off each end (to exclude edge effects) and were then subdivided into two 15 cm long sections. The two sections were placed in separate ziplock bags such that each tray provided two replicate bags of 10 x 15 cm bulked canes for washing. All samples were weighed then washed (with agitation) in 1% nitric acid for 30 mins. Washes were filtered through a Millipore AP25 glass fibre filter and an aliquot of each wash was sent to Hill Laboratories in Hamilton for copper analysis. Unsprayed ‘control’ canes were similarly washed and treated to determine background levels of copper present on each of the cane types.

A sample of canes of each type were weighed prior to spraying and then prior to washing to determine the correction factor for ‘field wet weight’ of canes. All copper residues in this report are presented as mg/kg (ppm) of field wet canes. Samples of canes were also oven dried to determine a correction factor for converting residues to ppm dry weight of canes. The mean dry weight of 10 samples of 10 canes was 50.57% of that of wet canes (CV = 4.4%).

Post-rain residue data was compared with initial copper deposits on canes which received no rain to determine rainfastness of residues after the nominated rain events. The relative rainfastness of each commercial spray treatment on the four types of canes was also determined. Duplicate residue analyses of each bulked sample was undertaken to confirm the reproducibility of residue data and data was compared using analysis of variance and LSD test (P=0.05) to determine the significance of treatment, cane type and rain events on residues.

Spreading of droplets (1.0 µl) of three treatments (Table 1) on canes were also determined and photographed.

HO canes

HN canes

GO canes

GN canes

Photo 2: The four types of canes used in the study: Hayward (H), Hort 16A (G), old (O), new (N)

Photo 3: Rain event setup

RESULTS

The background copper levels on canes were expected to be very low because they were deliberately sampled from orchards which had received no copper sprays during the current season. While background residues on new canes were as expected at <0.5 ppm (Tables 1 & 2, nil chemical), the residues on old canes were high, and those on Hort 16A (GO) canes were extremely high (> 9 ppm). It was subsequently confirmed that the GO canes had received two copper sulphate sprays (at 12 kg/ha each) on 4th & 15th June 2010, and background contamination from these sprays was still evident 12 months later. This contamination on GO and, to a lesser extent, HO canes was obviously very variable within the canes sampled and produced large variations in residues recovered from these two types of canes (Tables 1 & 2). While the data is corrected for background, this correction cannot account for any variations in residues between individual canes randomly selected for different treatments and rain intervals. As a result, residue data reported for old canes should be interpreted with caution.

Cane type had a significant effect (P=0.03) in that residues on HO canes were lower than on HN canes overall, but generally there was no difference between Hort 16A and Hayward, or old and replacement canes. Overall, there were no differences between the four commercial copper treatments applied at 600 L/ha, but they were all different to the Bordeaux mix applied at 2000 L/ha (Tables 1 & 2 and Figs 1-5).

Overall, rain had no effect on longevity of copper on canes; there was no significant difference (P=0.05) between residues on canes at zero time and after 100 mm rain. While there were some large variations in residues present, at all rain intervals and as a percentage of initial deposits, this is attributable mainly to the big variation in background residues present on old canes, and particularly on GO canes (Tables 1 & 2 and Figs 1-5). The longevity of copper on canes is also confirmed by these background residues, resulting from the copper sprays (24 kg/ha) applied 12 months earlier.

TABLE 1: Copper residues (ppm) from five commercial sprays remaining on Hayward old (O) and new (N) canes after increasing rain events. (All data corrected for mean background ppm)

Chemical	cane	Rain applied (mm total)					Cu loss after 100 mm rain (as % of no rain)
		0	25	50	75	100	
Nordox 75WG	HO	2.78	6.62	1.98	2.91	4.02	0
	HN	4.15	5.74	5.46	5.37	4.92	0
Kocide Opti	HO	1.68	2.93	3.18	0.79	2.71	0
	HN	3.16	2.28	2.26	1.96	2.59	18.0
Liquicop	HO	3.38	2.70	3.77	3.23	3.43	0
	HN	4.09	3.59	3.38	2.81	3.01	26.4
Cuprofix	HO	2.33	5.02	3.71	1.00	3.72	0
	HN	4.21	3.88	2.97	3.46	2.93	30.4
Bordeaux	HO	38.8	26.2	33.6	28.5	38.5	0.8
	HN	47.1	27.7	55.4	52.9	43.6	7.4
Nil (blank)	HO	2.15	-	-	-	-	-
	HN	0.49	-	-	-	-	-

TABLE 2: Copper residues (ppm) from five commercial sprays remaining on Hort 16A old (O) and new (N) canes after increasing rain events. (All data corrected for mean background ppm)

Chemical	cane	Rain applied (mm total)					Cu loss after 100 mm rain (as % of no rain)
		0	25	50	75	100	
Nordox 75WG	GO	7.57	3.01	6.88	2.56	2.13	71.9
	GN	5.31	5.75	5.10	4.06	5.71	0
Kocide Opti	GO	5.02	1.87	8.99	7.23	4.95	1.4
	GN	2.30	2.46	2.59	2.31	1.85	19.6
Liquicop	GO	9.24	1.50	0	1.07	9.06	1.9
	GN	2.78	2.91	2.76	3.00	3.00	0
Cuprofix	GO	4.25	8.90	1.07	8.39	1.16	72.7
	GN	4.65	3.90	2.91	3.42	2.53	45.6
Bordeaux	GO	33.6	32.8	42.2	31.1	28.6	14.9
	GN	37.1	31.0	53.3	38.2	33.2	10.5
Nil (blank)	GO	9.36	-	-	-	-	-
	GN	0.29	-	-	-	-	-

The inadvertent substitution of Du-Wett superspreader for Du-Wett Rainmaster sticker-spreader had no effect on the rain longevity of copper sprays. This was reported in an earlier copper residue study on kiwifruit leaves and fruit undertaken for Zespri (Gaskin, Steele & Horgan, April 2011). It was confirmed by a separate study on HN canes only, applying all treatments in 2000 L/ha without any adjuvant addition (Table 3). The zero time residues were lower in the original study, which applied concentrate sprays with Du-Wett (Table 1), because of over-wetting caused by the excessively high adjuvant use rate and the resultant loss of spray to run-off (cf. Tables 1 & 3). However, the proportional loss of copper after 100 mm rain was similar in treatments with or without Du-Wett (compare 'point' data for dilute chemical application on Figs 1-4). This result confirmed that Du-Wett can be used (at the correct use rate!) in concentrate copper sprays on canes, rather than the more expensive Du-Wett Rainmaster option, and it will not adversely affect longevity of copper residues. Superspreading adjuvants such as Du-Wett greatly increase the spread of spray droplets on canes and thus, increase spray coverage on cane surfaces markedly (Photos 4 & 5).

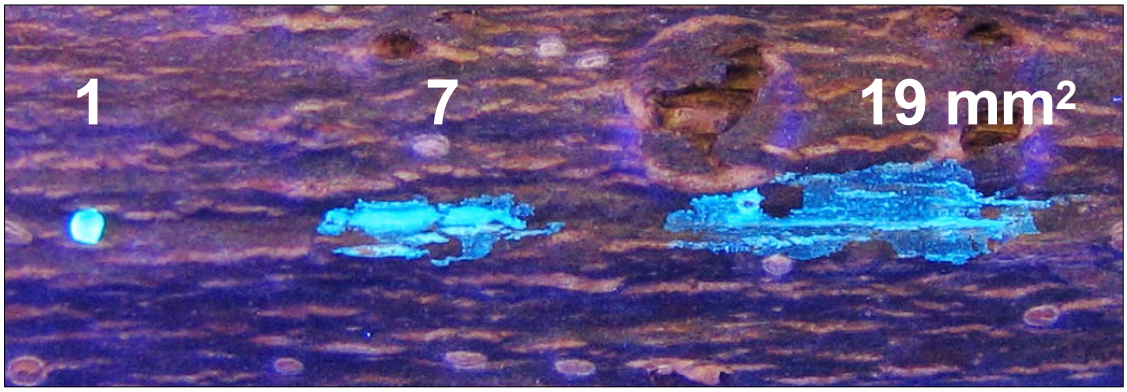


Photo 4: Comparative spreading of spray droplets (0.25 µl) containing Du-Wett (at 0, 50 & 100 ml/100 L), on Hayward old (HO) canes

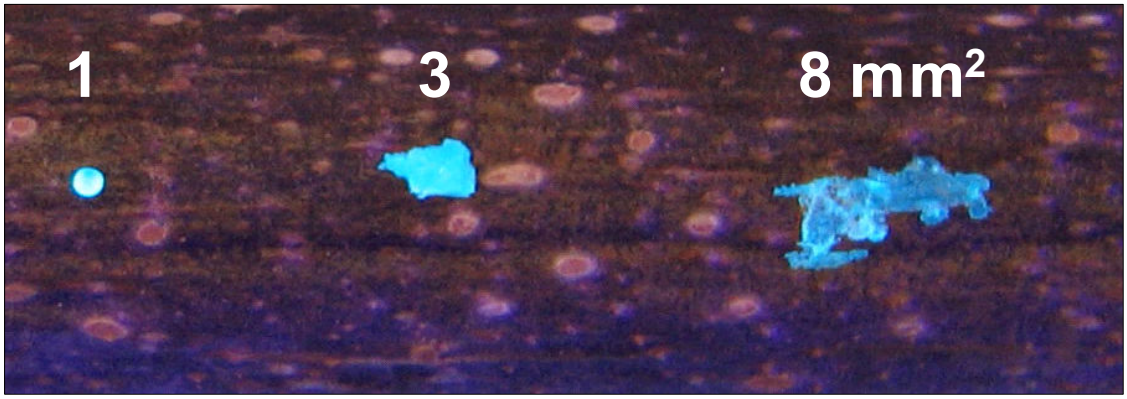


Photo 5: Comparative spreading of spray droplets (0.25 µl) containing Du-Wett (at 0, 50 & 100 ml/100 L), on Hayward new (HN) canes

Raining 100 mm on canes which had received dilute sprays resulted in losses of 7-25% of initial copper deposits (Table 3). Bordeaux mix appeared to be the least affected by rain and Kocide Opti the most. However, if the same amount of copper (e.g. 1 kg/ha) is applied in each spray then Kocide Opti and Nordox, for example, provide similarly high copper deposits initially and also after 100 mm rain (Table 3). Bordeaux spray (at 1 kg/ha) is retained least and has lowest residues after 100 mm rain. Thus the residues on canes generally reflect the different rates of copper applied in the sprays of each commercial product. Their relative efficacies were not determined in this study.

TABLE 3: Copper residues from four commercial sprays[1] on Hayward new (HN) canes, without rain and after 100 mm rain. (All data corrected for mean background ppm)

Chemical	Measured residues (ppm)		Cu loss post-rain (as % of initial deposit)	Normalised deposits[2] (ppm)	
	0 mm rain	100 mm rain		0 mm rain	100 mm rain
Nordox 75WG	9.1	8.0	12.1	11.0	9.7
Kocide Opti	4.9	3.7	24.5	12.6	9.5
Liquicop	3.7	3.4	8.1	7.9	7.2
Cuprofix	4.6	4.0	13.0	9.6	8.3
Bordeaux[3]	47.1	43.6	7.4	5.9	5.5
Nil (blank)	0.2	-	-	-	-

[1]all treatments applied in 2000 L/ha, no adjuvant addition
[2]assuming 1kg/ha Cu applied for each product
[3]data extracted from Table 1 for comparison with other treatments

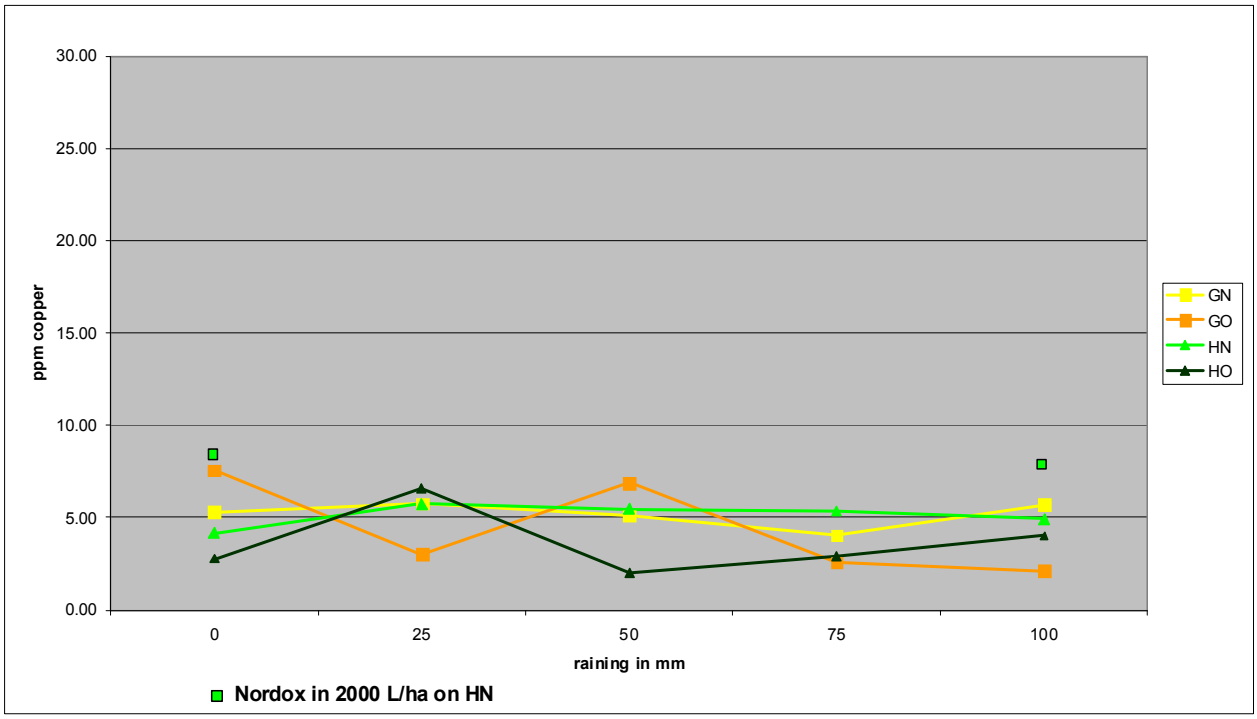


Fig. 1: Post-rain residues (ppm) of Nordox copper sprays (1.1 kg/600 L/ha + 0.1% Du-Wett) applied to Hort 16A (GO & GN) and Hayward (HO & HN) canes.

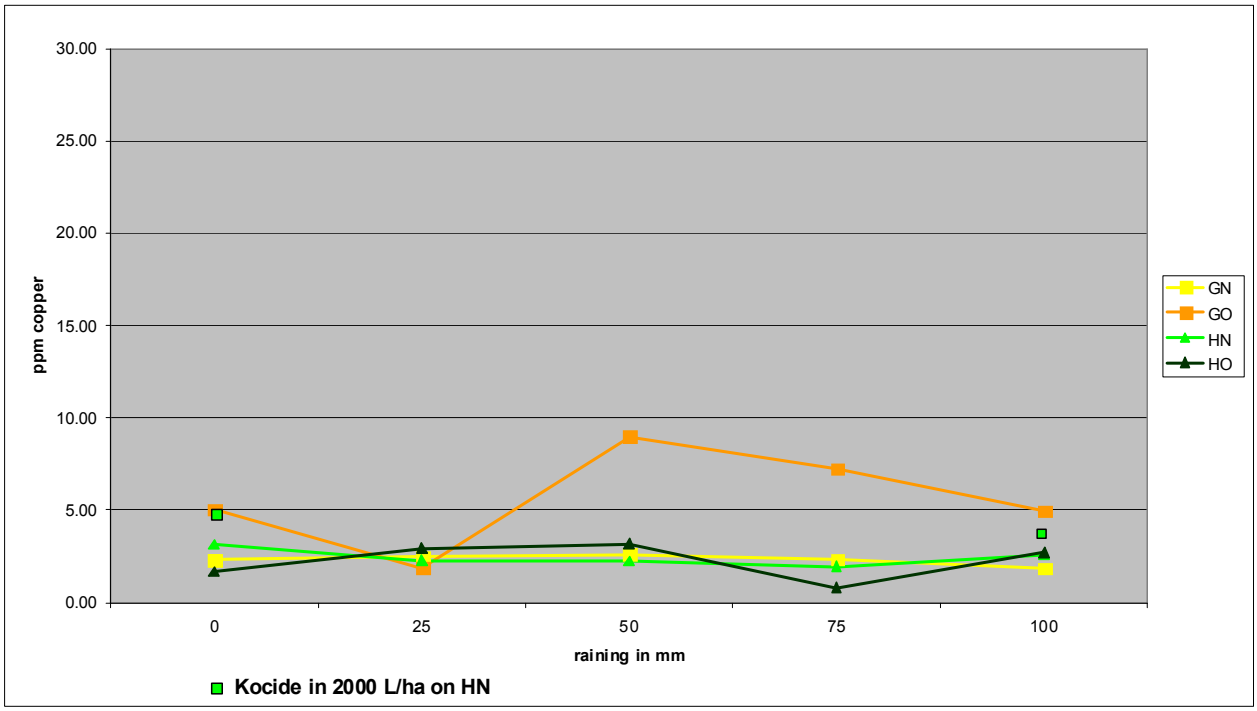


Fig. 2: Post-rain residues (ppm) of Kocide Opti copper sprays (1.3 kg/600 L/ha + 0.1% Du-Wet) applied to Hort 16A (GO & GN) and Hayward (HO & HN) canes.

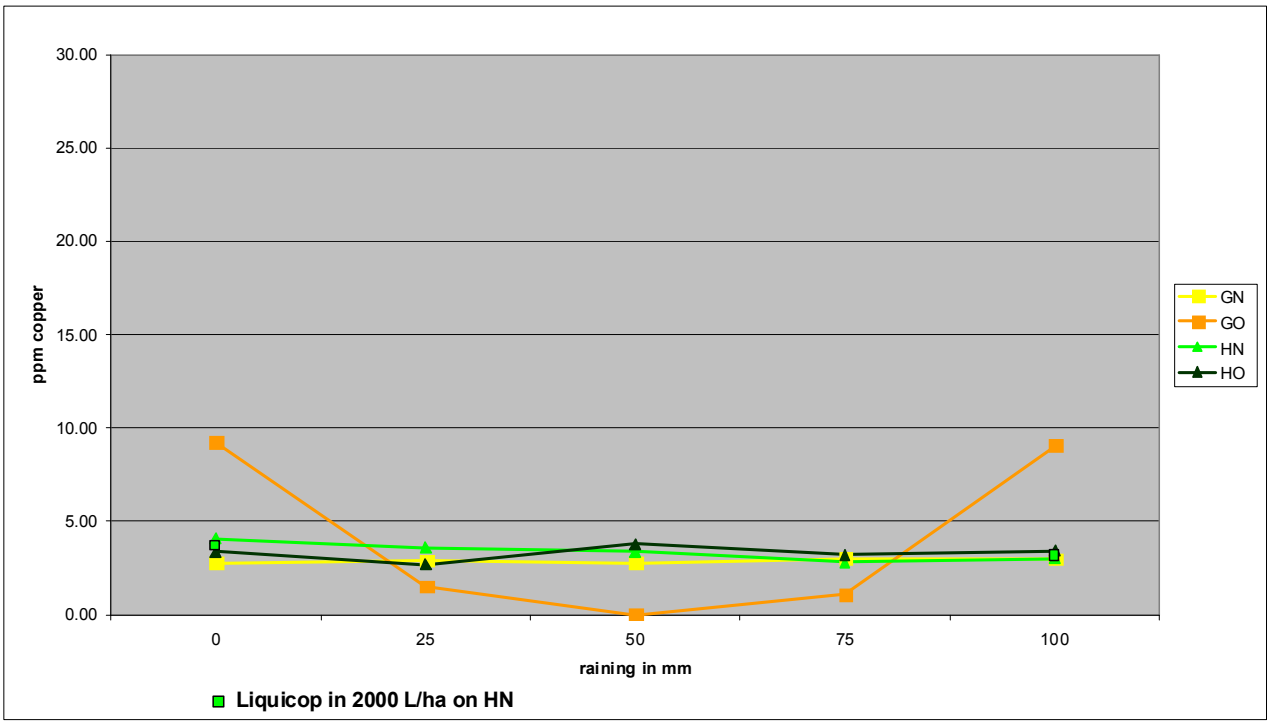


Fig. 3: Post-rain residues (ppm) of Liquicop copper sprays (5 L/600 L/ha + 0.1% Du-Wet) applied to Hort 16A (GO & GN) and Hayward (HO & HN) canes.

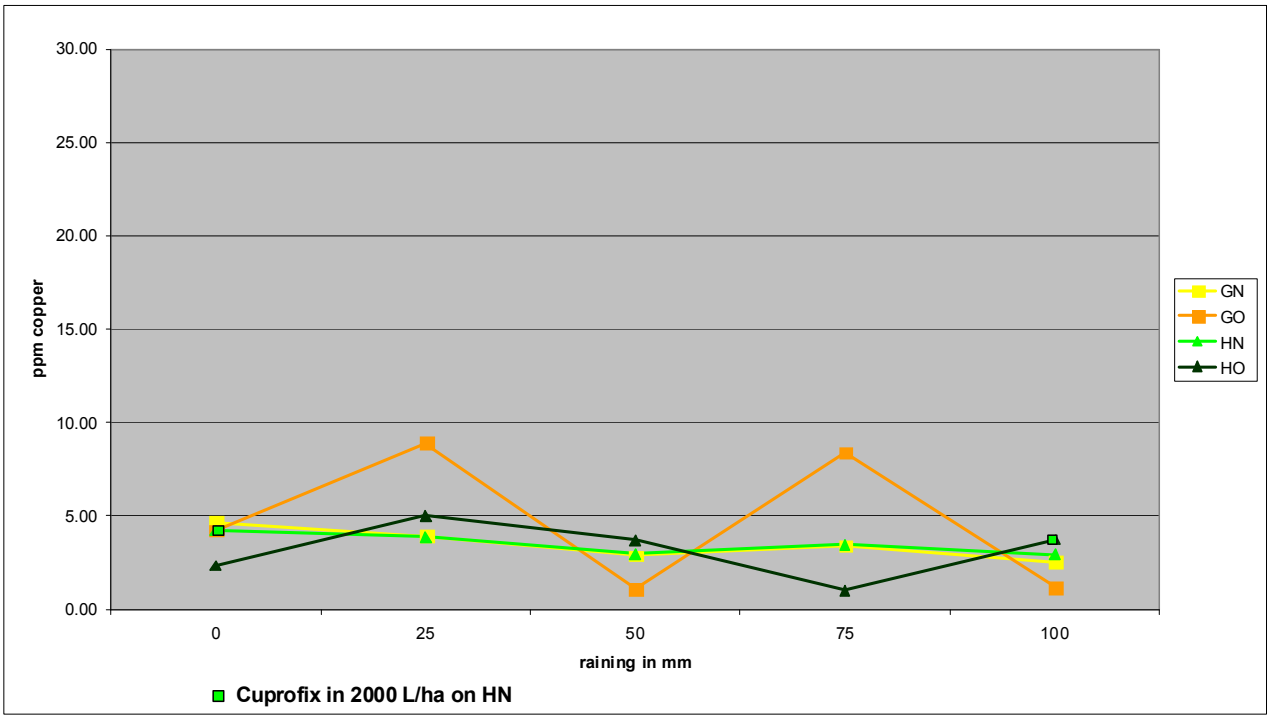


Fig. 4: Post-rain residues (ppm) of Cuprofix Disperss copper sprays (2.4 kg/600 L/ha + 0.1% Du-Wet) applied to Hort 16A (GO & GN) and Hayward (HO & HN) canes.

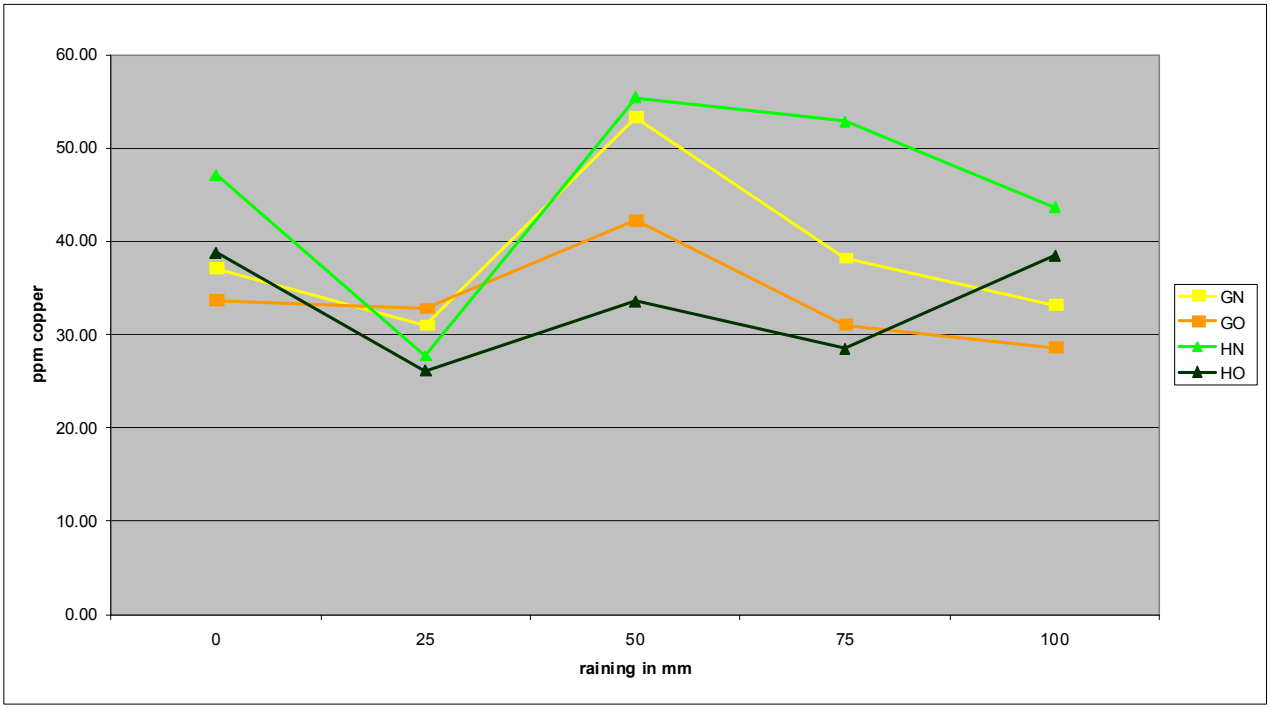


Fig. 5: Post-rain residues (ppm) of Bordeaux 10.8.1000 copper sprays (in 2000 L/ha) applied to Hort 16A (GO & GN) and Hayward (HO & HN) canes.

CONCLUSIONS

- Copper sprays applied to kiwifruit canes are highly resistant to rain wash-off.
- After 100 mm rain, generally more than 75% of initial spray deposits on new canes (and probably on old canes also) was still present.
- Hayward new canes retained highest copper residues and Hayward old canes retained least copper, but generally there was little difference in performance between Hort 16A and Hayward, or old and new canes.
- Du-Wett, and any similar superspreader adjuvant, will not affect longevity of copper residues on canes.
- Du-Wett, and similar superspreader adjuvants (e.g. Du-Wett Rainmaster and Driftstop), improve the spreading and coverage of copper sprays on canes.

STUDY 2: EFFECT OF RAINFALL ON ORGANIC COPPER SPRAY RESIDUES ON HAYWARD REPLACEMENT CANES

This study investigated the effect of up to 100 mm of moderately heavy rain (simulated) applied to canes which had previously had dilute copper sprays containing Excel Organic oil applied. The aim was to confirm the residues of sprays retained on the canes pre-rain and their relative resistance to wash-off by rain.

Methods and Materials

Hayward kiwifruit replacement/new canes were freshly sampled by Zespri in June 2011, immediately prior to the trial, from a block which had received no copper sprays in the current season. They were stored, used and processed as reported in Study 1.

Treatments were as nominated by Zespri:

1. Nordox 75WG (750 g Cu, Gro-Chem); 1.4 kg/2000 L/ha+ 1% Excel Organic oil
2. Nordox 75WG (750 g Cu, Gro-Chem); 1.4 kg/2000 L/ha+ 2% Excel Organic oil
   (Both treatments = 1.05 kg Cu)

Spreading of droplets (1.0 µl) of three treatments (Table 1) on canes were also determined and photographed.

RESULTS

The results in this study were compared to the Nordox data generated in Study 1, Table 3. Addition of oil had little effect on initial deposits, at best a 14% increase in retention was achieved (Table 1). After 100 mm rain, residues on canes were similar for all treatments and the oil at 1% and 2% was judged to have no effect on the resistance of the copper spray to rain wash-off (Table 1 & Fig. 1).

TABLE 1: Copper residues (ppm) from organic copper sprays[1] remaining on Hayward new (HN) canes after increasing rain events. (All data corrected for mean background ppm)

Chemical	Rain applied (mm total)				Cu loss after 100 mm rain (as % of no rain)
	0	25	50	100	
Nordox 75WG[2]	9.1	-	-	8.0	12.1
+ Excel Organic 1%	10.4	10.5	9.0	8.8	15.4
+ Excel Organic 2%	9.7	9.9	8.7	9.2	5.2
Nil (blank)	0.2	-	-	-	-

[1]all treatments applied in 2000 L/ha
[2]data extracted from Study 1, Table 3 for comparison with oil treatments

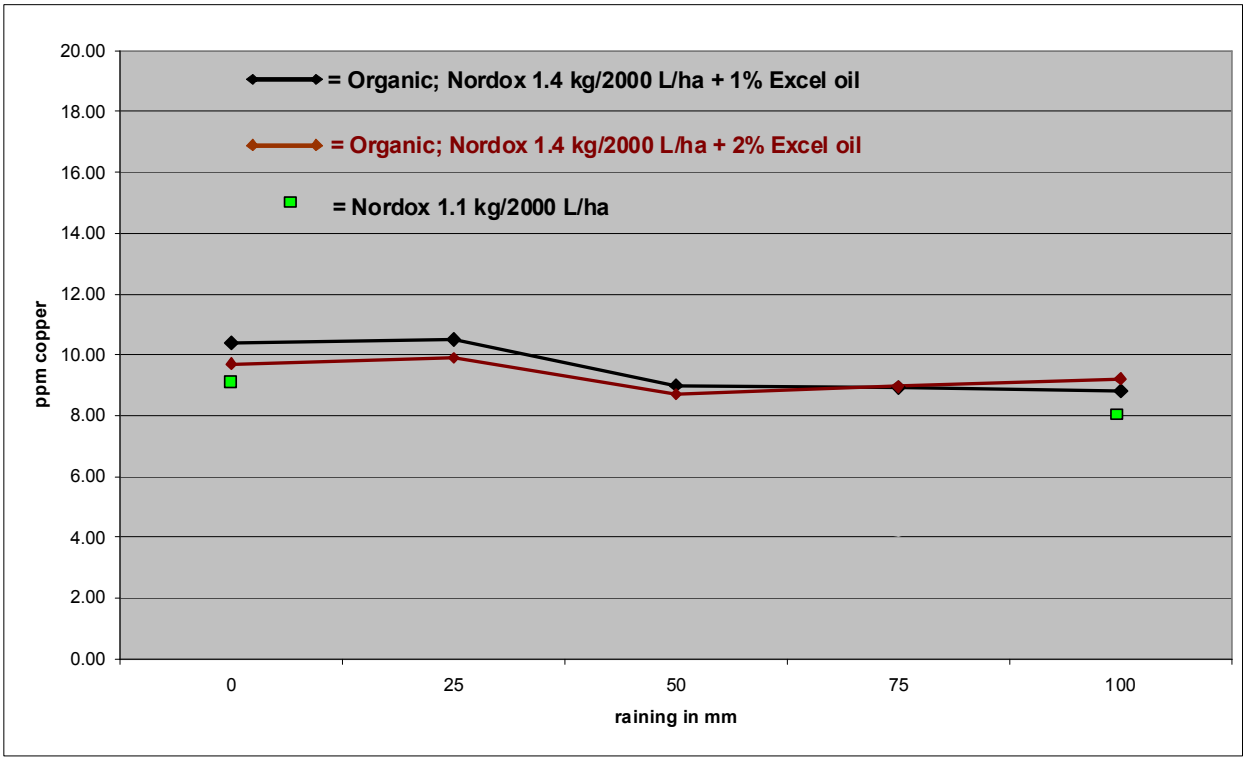


Fig. 1: Post-rain residues (ppm) of Nordox copper sprays applied at 2000 L/ha to Hayward new (HN) canes.

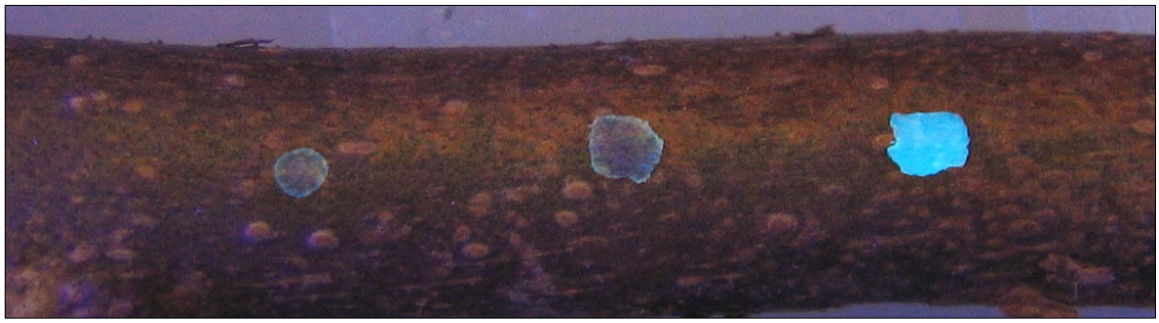
The spreading of Nordox spray solution on Hayward canes was not improved significantly by addition of 1% Excel Organic oil (Table 2), although there was a small trend of increased coverage with oil on new canes. Addition of 2% Excel oil increased droplet spreading on both cane ages but this was by less than a factor of two. The relative spreads are demonstrated in Photos 1 & 2. Note that these droplets are 1 µl in volume compared to the 0.25 µl volume droplets used in Study 1 (Photos 4 & 5).

Table 2: Spreading (mm^2) of Nordox spray droplets (1 µl) on Hayward canes

Tmt #	Chemical	New canes	Old canes
1	Nordox 75WG	3.7 c	5.3 bc
2	+ Excel Organic 1%	6.0 abc	5.5 bc
3	+ Excel Organic 2%	6.9 ab	8.0 a

Means sharing common postscripts are NSD (P=0.05)

HN



HO

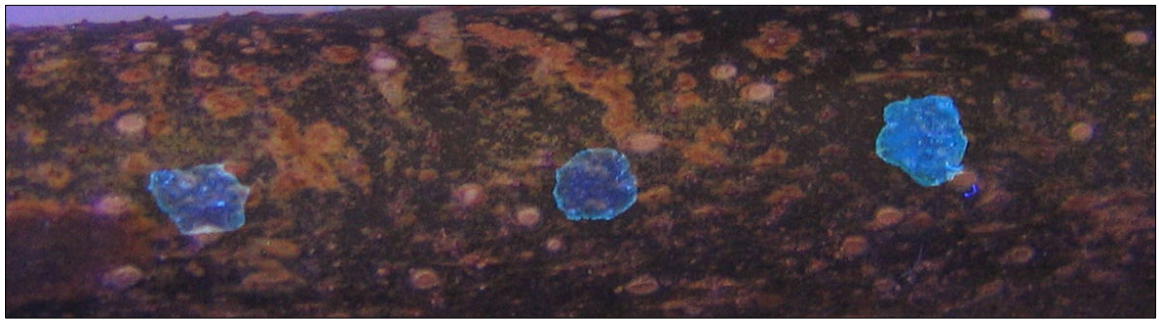


Photo 1: Comparative spreading of Nordox spray droplets (1 µl) on Hayward new (HN) and Hayward old (HO) canes. Left to right are Tmts 1-3 (Table 2)

CONCLUSIONS

- Nordox copper sprays applied to organic kiwifruit canes are highly resistant to rain wash-off.
- After 100 mm rain, more than 84% of initial spray deposits on new canes (and possibly on old canes also) were still present.
- Excel Organic oil did not improve the retention of dilute copper sprays on canes, or affect the resistance of deposits to rain wash-off.
- Excel Organic oil had very little effect on droplet spreading on canes; droplet coverage increased slightly with 2% but not with 1% oil.

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Thanks to the companies who supplied products and the growers who allowed canes to be sampled from their orchards. Scion Nursery gave us access to their rain-making facility. Alison Forster, Rebecca van Leeuwen, and Justin Nairn (PPC_{NZ}) provided technical assistance.

REFERENCES

Gaskin RE, Steele KD, Horgan DB, April 2011. *Studies to determine the rainfastness of residues of commercial copper sprays on kiwifruit.* Report to Zespri Ltd, March 2011. 22 pp.

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