Report to Zespri Group Ltd

Studies to determine the rainfastness of residues of commercial copper sprays on kiwifruit

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EXECUTIVE SUMMARY

Three studies were undertaken to determine (1) how rainfall affects residues on Hort 16A and Hayward fruit after 4x repeated applications of commercial copper sprays, (2) how rainfall affects copper residues on Hort 16A and Hayward fruit, and upper and lower leaf surfaces, after a single dilute spray application, and (3) the effect of adjuvants on rainfastening of a concentrated commercial copper spray on leaf surfaces and fruit.

The commercial sprays used were Nordox 75WG (Gro-Chem), Champ DP (Nufarm) and Kocide Opti (DuPont). Spray application was made to freshly sampled fruit and leaves with a moving head tracksprayer. Rain was applied at moderate-heavy intensity in varying amounts up to 50 mm. Copper residue analyses were undertaken according to Zespri protocols by Hill Laboratories. The findings were:

Fruit

- Up to four sequential copper sprays on fruit are unlikely to exceed MRLs, even in the absence of rain. Maximum pre-rain copper residues were approx. 10 ppm.
- All copper sprays on fruit of both varieties were highly resistant to rain wash-off.
- After 50 mm of rain, residues ranged from 3-6 ppm on Hort 16A fruit and 5-7 ppm on Hayward that had been sprayed with 4x recommended chemical rates.
- After 50 mm rain, maximum residues on Hort 16A and Hayward fruit that had received a single spray were 3.6 ppm and 3.0 ppm, respectively.
- At the rates tested, highest fruit residues are likely with Nordox and Champ, and least with Kocide Opti.

Foliage

- All copper sprays were moderately resistant to rain wash-off from leaves, both upper and lower surfaces of both varieties.
- At least 25 mm of rain was required to remove 50% of the initial copper residues.
- After 50 mm rain, residues on leaf upper surfaces ranged from 8-44 ppm and 11-36 ppm, and on lower surfaces from 25-78 ppm and 22-64 ppm, on Hort 16A and Hayward respectively.
- The concentration of copper on foliage required to control Psa is currently unknown. While the leaf residues determined here seem promisingly high, control will depend on the uniformity of distribution of copper on leaves. The accumulation of copper at the leaf margins after heavy rain events will adversely affect this.

Adjuvant rainfastening

- Kocide is a very “sticky” formulation and adjuvants are unlikely to markedly increase or reduce its resistance to rain wash-off.

- Du-Wett addition (350 ml/ha) to 2x concentrate sprays will not reduce the rainfastness of Kocide, but its effect at higher concentrations is unknown.

- Du-Wett Rainmaster (1 L/ha) can improve the longevity of copper residues in ≤ 50 mm rain on easy-to-wet upper leaf surfaces, but the adjuvant has little rainfastening effect on residues on the hairy lower surfaces.

- Du-Wett and Du-Wett Rainmaster will provide more thorough leaf coverage of concentrate copper sprays than will dilute sprays without adjuvant addition. The premise being that coverage equals protection.

- The adjuvants tested had little or no effect on residues on fruit.

Studies to determine the rainfastness of residues of commercial copper sprays on kiwifruit

Introduction

The infection of kiwifruit by *Pseudomonas syringae pv Actinidiae* (Psa) occurs via airborne spores, meaning it is easily spread by heavy rain, strong winds, animals and humans. The bacterium infects the plant through natural apertures (stomata and leaf axis) on leaves and wounds on the vine. Copper sprays are known to have some protectant activity against Psa, but inappropriate use can damage kiwifruit foliage and blemish fruit. In addition, excessive use of copper sprays may exceed MRLs for export markets and could create considerable market access and/or inventory management problems for ZESPRI.

The three separate studies reported here were undertaken to determine (1) how rainfall affects residues on Hort 16A and Hayward fruit after 4x repeated applications of commercial copper sprays, (2) how rainfall affects copper residues on Hort 16A and Hayward fruit, and upper and lower leaf surfaces, after a single dilute spray application, and (3) the effect of adjuvants on rainfastening of a concentrate commercial copper spray on leaf surfaces and fruit.

STUDY 1: EFFECT OF RAINFALL ON 4X “NORMAL” COPPER SPRAY RESIDUES ON HORT 16A AND HAYWARD FRUIT

This study investigated the effect of up to 50 mm of moderately heavy rain (simulated) applied to fruit surfaces which had previously had the equivalent of four cumulative dilute copper sprays applied. The aim was to confirm the maximum residues of three commercial copper sprays remaining on the fruit post-rain and their relative resistance to wash-off by rain.

Methods and Materials

Hort 16A and Hayward kiwifruit were freshly sampled immediately prior to the trial from unsprayed blocks nominated by Zespri. They were handled throughout with gloves, to minimise any disruption to surfaces, and stored at 4°C in export fruit boxes until used. Immediately prior to spraying, fruit were mounted at an angle on nails on boards (as 20 rep fruit in 5 rows), upside down, to ensure the drip (lowest) point was lower than the point of nail attachment (Photo 1). Fruit were not touching, or vertically shaded by each other.

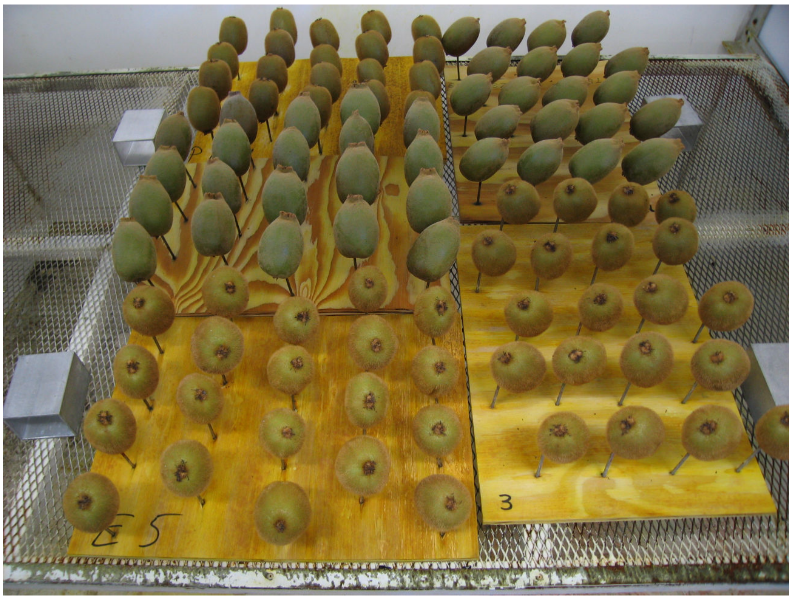

Photo 1: Hort 16A and Hayward fruit set up on nail boards (20 replicates per board)

Treatments were as nominated by Zespri, i.e. sprayed at 4x the recommended rate for each chemical:

1. Nordox 75WG (750 g CuO WDG, Gro-Chem); 4.4 kg/2000 L/ha (= 3.3 kg Cu)
2. Kocide Opti (300 g CuOH WDG, Du Pont); 5.2 kg/2000 L/ha (= 1.6 kg Cu)
3. Champ DP (375 g CuOH, dry prill, Nufarm) 8.4 kg/2000 L/ha (= 3.2 kg Cu)

All treatments contained tartrazine dye at 5 g/L to accurately determine spray delivery volumes. All treatments were applied through a twin cap nozzle set-up in the PPC_{NZ} Tracksprayer, with two 8004EVS nozzles, at 150 kPa pressure. The nozzle was mounted 1.5 m above the fruit to ensure terminal velocity at droplet impact. It is not possible to totally simulate air-blast spray application in the tracksprayer. 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. Nozzle selection was discussed with and confirmed by Bill May.

The sprayed fruit (100 per treatment of each kiwifruit variety) were left to dry overnight. The following day, rain was applied to the dry fruit at 10 mm/h, which equated to a moderately heavy rain event, for varying time intervals up to 5 h. Thus 20 fruit of each variety which had been pre-sprayed with one of the three treatments received no rain, or a nominal 12, 25, 37 or 50 mm of total rain. Fruit were left under cover for 24 h to dry then bagged and deep frozen. The samples (containing 20 bulked fruit) were delivered frozen to Hill Laboratories in Hamilton for standard copper analysis as routinely provided to Zespri.

Post-rain residue data was compared with copper deposits on fruit which had received no rain to determine maximum residues (ppm) remaining after the nominated rain events. The relative rainfastness of each commercial spray treatment on the two varieties of fruit was also determined. No statistical tests were possible as fruit were bulked for a single residue analyses of each sample.

RESULTS

The different rates of copper applied in each treatment were generally reflected in the residues detected on fruit (Table 1). However, with no rain applied, more Kocide Opti spray was retained on fruit than Nordox; e.g. 5.8 ppm Kocide would equal 12.2 ppm Nordox if both sprays were retained equally. Less Champ spray was retained on Hort 16A, but more on Hayward, than either Kocide or Nordox.

The pre-rain residues from 4x the normal copper sprays applied were in the range 5-10 ppm (Table 1). This provides a considerable safety margin for the EU MRLs for fruit, at ca. 20 ppm.

All three copper sprays had good resistance to wash-off by rain (Table 1 & Fig. 1). Rain generally removed less copper spray from Hayward, relative to Hort 16A fruit, presumably due to the hairy nature of the former. Residues of all three formulations declined little with up to 50 mm rain (Fig. 1). Higher residues are likely with sequential applications of Nordox and Champ, than with Kocide Opti.

TABLE 1: Copper residues (ppm) from three commercial sprays (applied at 4x recommended rate in 2000 L/ha) remaining on Hort 16A (gold) and Hayward (green) kiwifruit after increasing rain events

Tmt #	Chemical	Variety	Rain applied (mm total) 0	12	25	37	50
1	Nordox 75WG	Gold	9.0	7.5	7.6	7.3	6.3
	Nordox 75WG	Green	9.6	6.8	7.4	8.1	7.2
2	Kocide Opti	Gold	5.8	3.3	3.6	2.8	3.3
	Kocide Opti	Green	5.0	3.1	5.1	3.8	5.1
3	Champ DP	Gold	7.6	5.6	5.1	5.4	5.4
	Champ DP	Green	10.3	6.5	7.1	7.7	6.7
-	Nil (blank)	Gold	1.12	-	-	-	-
-	Nil (blank)	Green	0.91	-	-	-	-

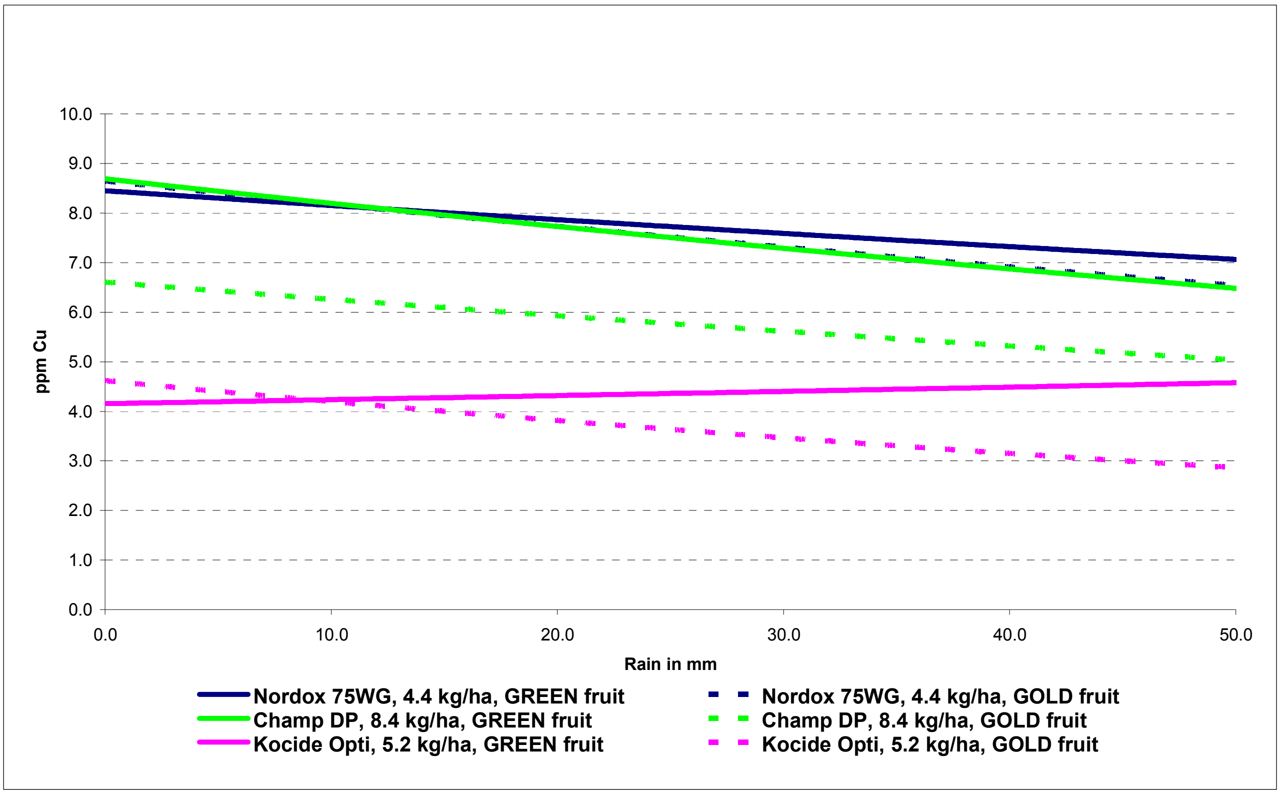

Fig. 1: Post-rain residue trends (ppm) of three copper sprays applied to Hort 16A and Hayward fruit

Kocide was the most rainfast on Hayward fruit, i.e. residues declined least as a % of original deposits, but the least rainfast on Hort 16A (Table 2 & Fig. 2). Nordox was the most rainfast on Hort 16A and its residues showed slightly greater longevity than Champ. The expectation is that the Nordox spray should be less water soluble than either Champ or Kocide due to the differences in their chemistry. CuO (Nordox) is insoluble in water, while CuOH (Champ and Kocide) is slightly soluble at ca 8 ppm.

TABLE 2: Copper residues (as % of initial spray deposits) from three commercial sprays (applied at 4x recommended rate in 2000 L/ha) remaining on Hort 16A (gold) and Hayward (green) kiwifruit after increasing rain events

Tmt #	Chemical	Variety	Rain applied (mm total) 0	12	25	37	50
1	Nordox 75WG	Gold	100	84	85	82	71
	Nordox 75WG	Green	100	71	77	85	75
2	Kocide Opti	Gold	100	58	62	48	58
	Kocide Opti	Green	100	61	102	76	102
3	Champ DP	Gold	100	74	67	71	71
	Champ DP	Green	100	63	70	75	65

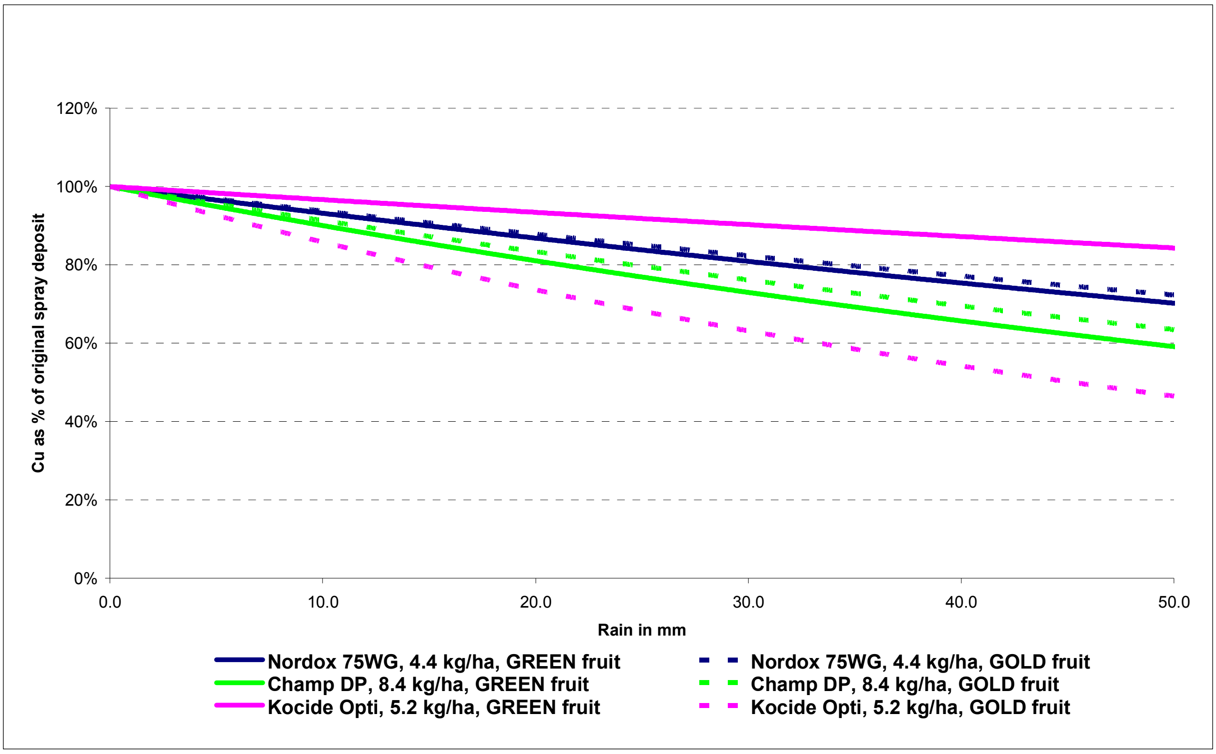

Fig. 2: Post-rain residue trends (as % of initial spray deposits) of three copper sprays applied to Hort 16A and Hayward fruit

CONCLUSION

- Up to four sequential copper sprays are unlikely to exceed MRLs, even in the absence of rain. Maximum pre-rain copper residues were approx. 10 ppm.
- All sprays were rainfast on both fruit varieties. After 50 mm of rain residues ranged from 3-6 ppm on Hort 16A fruit and 5-7 ppm on Hayward.
- At the rates tested, highest fruit residues are likely with Nordox and Champ, and least with Kocide Opti. *The relative efficacies of these treatments were not determined in this study.*

STUDY 2: EFFECT OF RAINFALL ON COPPER SPRAY RESIDUES ON KIWIFRUIT FOLIAGE AND FRUIT

This study investigated the effect of up to 50 mm of moderately heavy rain (simulated) applied to Hort 16A and Hayward fruit and foliage (adaxial and abaxial leaf surfaces) which had previously had typical dilute copper sprays applied. The aim was to confirm the residues of three commercial copper sprays remaining on plant surfaces post-rain and their relative resistance to wash-off by rain.

Methods and Materials

Fruit were sampled, treated and processed as described in Study 1. Leaves of Hort 16A and Hayward were freshly sampled on the day of the trial from unsprayed orchards. They were mounted at 45 degree angles on chicken wire mesh supports. Leaves were placed with either their adaxial or abaxial surface (5 replicates of each per support) exposed to the sprayer (Photo 2).

Photo 2: Leaves set up on wire cages for spraying

Treatments were sprayed at the recommended rate for each chemical, as advised by Zespri:

1. Nordox 75WG (750 g CuO WDG, Gro-Chem); 1.1 kg/2000 L/ha
2. Kocide Opti (300 g CuOH WDG, Du Pont); 1.3 kg/2000 L/ha
3. Champ DP (375 g CuOH, dry prill, Nufarm) 2.1 kg/2000 L/ha

The sprayed leaves (50 x 2 surfaces sprayed per treatment) were left for up to 2 h to dry. Some slight leaf curling occurred with some leaves during this time and where this occurred, leaves were flattened and secured with clothes pegs prior to raining on. Rain was applied to the dry leaves at 10 mm/h, which equated to a moderately heavy rain event, for varying time intervals up to 5 h. Thus 20 leaves of each variety, comprising of 10 upper and 10 lower sprayed surfaces, which had been pre-sprayed with one of the three treatments, received no rain, or a nominal 12, 25, 37 or 50 mm of total rain. Leaves were left under cover for 12 h to dry then bagged and deep frozen. The samples (each containing 10 bulked leaves) were delivered frozen to Hill Laboratories in Hamilton for standard copper analysis.

Post-rain residue data was compared with copper deposits on fruit and foliage which had received no rain to determine maximum residues (ppm) remaining after the nominated rain events. The relative rainfastness of each commercial spray treatment on the fruit and foliage of the two varieties was also determined. All graphed data from tables are included in the Appendix.

Results

Hort 16A foliage

As seen on fruit in Study 1, the residues on foliage generally reflected the different rates of copper applied in each spray (Table 3). With no rain, Nordox and Champ sprays were similarly retained (ca 95 ppm mean Cu residues), while Kocide residues were proportionally slightly higher (56 ppm mean residues with Kocide equates to 118 ppm with Nordox if amounts of spray retained were equivalent). The copper residues on leaves were far higher than on fruit due to the large capture area of foliage proportional to the leaf weight. Surface residues are diluted on fruit by the large fruit mass.

Spray residues (and retention) were consistently higher on the lower leaf surface of Hort 16A (Table 3 and Fig. 3), due to spray run-off from the smooth upper leaf surface and the large volume-holding capacity of the hairs on the lower leaf. Residue wash-off rates were similar on both leaf surfaces. The hairy lower surface potentially shielded dried residues from rain more than the hairless upper surface and accumulation of copper at the leaf margins with high rainfall was less obvious on the lower surface. While residues appeared to decay relatively slowly with rain, this may be misleading with high rainfall (≥25 mm) events. In these, copper accumulation at leaf margins was visible and thus residues over the rest of the leaf must have been depleted. The copper residues (ppm) required to control Psa on leaf surfaces are unknown at this stage.

TABLE 3: Copper residues (ppm) from three commercial sprays (applied at recommended rate in 2000 L/ha) remaining on Hort 16A foliage after increasing rain events

Tmt	Chemical	Leaf surface	Rain applied (mm total)				
#			0	12	25	37	50
1	Nordox 75WG	Upper	83	60	55	47	44
	Nordox 75WG	Lower	114	110	98	83	78
		mean	*99*	*85*	*76*	*65*	*61*
2	Kocide Opti	Upper	29	13	10	10	8
	Kocide Opti	Lower	84	53	39	31	25
		mean	*56*	*33*	*25*	*20*	*17*
3	Champ DP	Upper	59	33	38	16	14
	Champ DP	Lower	118	89	100	73	52
		mean	*88*	*61*	*69*	*44*	*33*
	Nil (Blank)	mean	3	-	-	-	-

As with fruit in Study 1, Nordox residues (ppm) were highest and Kocide lowest on Hort 16A foliage (Table 3). Nordox residues declined least with rain (Table 4 and Fig. 4) and less quickly than the more water-soluble Champ and Kocide formulations.

TABLE 4: Copper residues (as % of initial spray deposits) from three commercial sprays (applied at recommended rate in 2000 L/ha) remaining on Hort 16A foliage after increasing rain events

Tmt #	Chemical	Leaf surface	Rain applied (mm total) 0	12	25	37	50
1	Nordox 75WG	Upper	100	72	66	57	53
	Nordox 75WG	Lower	100	96	86	73	68
2	Kocide Opti	Upper	100	45	35	35	28
	Kocide Opti	Lower	100	63	46	37	30
3	Champ DP	Upper	100	56	64	27	24
	Champ DP	Lower	100	75	85	62	44

Hayward foliage

As with Hort 16A, the residues on Hayward foliage generally reflected the different rates of copper applied except that the initial retention of Nordox was uncharacteristically high (Table 5). The same relativities were maintained as for Hort 16A in that lower surfaces retained more spray and had higher residues, and Nordox and Champ residues on leaf surfaces were consistently higher than Kocide (Fig. 5). There was no consistent pattern of rain reducing residues faster on one variety than the other (Table 4 vs Table 6).

TABLE 5: Copper residues (ppm) from three commercial sprays (applied at recommended rate in 2000 L/ha) remaining on Hayward foliage after increasing rain events

Tmt #	Chemical	Leaf surface	Rain applied (mm total) 0	12	25	37	50
1	Nordox 75WG	Upper	86	72	47	52	36
	Nordox 75WG	Lower	169	110	83	70	57
		mean	*128*	*91*	*65*	*61*	*46*
2	Kocide Opti	Upper	39	28	19	15	11
	Kocide Opti	Lower	56	29	29	24	22
		mean	*48*	*28*	*24*	*19*	*16*
3	Champ DP	Upper	66	42	34	37	28
	Champ DP	Lower	112	76	71	75	64
		mean	*89*	*59*	*52*	*56*	*46*
	Nil (Blank)	mean	3	-	-	-	-

TABLE 6: Copper residues (as % of initial spray deposits) from three commercial sprays (applied at recommended rate in 2000 L/ha) remaining on Hayward foliage after increasing rain events

Tmt #	Chemical	Leaf surface	Rain applied (mm total) 0	12	25	37	50
1	Nordox 75WG	Upper	100	84	55	60	42
	Nordox 75WG	Lower	100	65	49	41	34
2	Kocide Opti	Upper	100	72	49	38	28
	Kocide Opti	Lower	100	52	52	43	39
3	Champ DP	Upper	100	64	52	56	42
	Champ DP	Lower	100	68	63	67	57

Fruit

The trends from this single spray application were similar to the 4x rate applications in Study 1. As expected, residues were lower (Table 7), but not 4x lower, suggesting that there was a limit to the amount of copper that could be retained on fruit surfaces from a concentrated spray application. Highest residues were measured from Nordox and Champ sprays and were similar on both varieties (Fig. 7). All residues were below 4 ppm, which corresponds well with copper residues measured in the field by Zespri (Shane Max, pers. com.), and up to 50 mm rain had little effect on reducing these residue levels.

TABLE 7: Copper residues (ppm) from three commercial sprays (applied at recommended rate in 2000 L/ha) remaining on Hort 16A (gold) and Hayward (green) fruit after increasing rain events

Tmt #	Chemical	Variety	Rain applied (mm total) 0	12	25	37	50
1	Nordox 75WG	Gold	3.3	3.2	3.1	2.9	3.6
	Nordox 75WG	Green	3.3	3.4	3.4	3.0	3.0
2	Kocide Opti	Gold	2.2	1.9	2.3	2.3	2.6
	Kocide Opti	Green	1.8	1.8	1.9	1.8	1.6
3	Champ DP	Gold	3.0	2.8	2.4	1.9	1.7
	Champ DP	Green	3.7	3.3	2.9	2.3	2.6
-	Nil (Blank)	Gold	1.1	-	-	-	-
-	Nil (Blank)	Green	0.9				

Kocide was the most resistant to rain wash-off on both varieties and Champ the least resistant (Table 8 & Fig. 8). Because of the low use rate of Kocide, this still resulted in lower residues than for the other two products. The relative efficacies of the three products at the residue levels detected are not known.

TABLE 8: Copper residues (as % of initial spray deposits) from three commercial sprays (applied at recommended rate in 2000 L/ha) remaining on Hort 16A (gold) and Hayward (green) fruit after increasing rain events

Tmt #	Chemical	Variety	Rain applied (mm total) 0	12	25	37	50
1	Nordox 75WG	Gold	100	97	94	88	109
	Nordox 75WG	Green	100	103	103	91	91
2	Kocide Opti	Gold	100	86	105	105	118
	Kocide Opti	Green	100	100	106	100	89
3	Champ DP	Gold	100	93	80	63	57
	Champ DP	Green	100	89	78	62	70

CONCLUSIONS

- All copper sprays were moderately resistant to rain wash-off from leaves, both upper and lower surfaces of both varieties.

- At least 25 mm of rain was required to remove 50% of the initial copper residues on leaves.

- After 50 mm rain, residues on leaf upper surfaces ranged from 8-44 ppm and 11-36 ppm, and on lower surfaces from 25-78 ppm and 22-64 ppm, on Hort 16A and Hayward respectively.

- The concentration of copper on foliage required to control Psa is currently unknown. While the leaf residues determined here seem promisingly high, control will depend on the uniformity of distribution of copper on leaves. The accumulation of copper at the leaf margins after heavy rain events will adversely affect this.

- All copper sprays on fruit were highly resistant to rain wash-off.

- After 50 mm rain, maximum residues on Hort 16A and Hayward fruit were 3.6 ppm and 3.0 ppm, respectively.

STUDY 3: EFFECT OF ADJUVANTS ON THE RAINFASTNESS OF A CONCENTRATE COPPER SPRAY ON KIWIFRUIT FOLIAGE AND FRUIT

This study investigated the effect of up to 50 mm of moderately heavy rain (simulated) applied to Hort 16A and Hayward fruit and foliage (adaxial and abaxial leaf surfaces) which had previously been sprayed with a concentrate copper spray containing an adjuvant necessary to maximise spray deposition of the concentrated sprays. The aim was to confirm the effect of the adjuvants on the resistance of the copper residues to wash-off by rain.

Methods and Materials

Fruit and foliage of Hort 16A and Hayward were sampled, treated and processed as described in Studies 1&2. Treatments were:

1. Kocide Opti 1.3 kg/1000 L/ha + 700 ml Du-Wett Rainmaster (DWRM)
2. Kocide Opti 1.3 kg/1000 L/ha + 1000 ml Du-Wett Rainmaster (DWRM)
3. Kocide Opti 1.3 kg/1000 L/ha + 350 ml Du-Wett (DW)

Rain was applied to pre-sprayed, dried surfaces as a 25 and 50 mm event. Post-rain residue data was compared with copper deposits on fruit and foliage which had received no rain to determine the relative rainfastness of each treatment on the fruit and foliage of the two varieties. The three treatments were also compared to the non-adjuvant dilute sprays applied in Study 2.

Results

Hort 16A foliage and fruit

All adjuvant treatments rainfastened 2x concentrated Kocide sprays applied to the easy-to-wet upper leaf surface (Table 9 and Fig. 9) in comparison to a dilute (2000 L/ha) spray. The higher DWRM and the DW sprays both increased markedly the initial deposits retained on this leaf surface. In contrast, the adjuvants had little effect on residues or rainfastness on the lower leaf surface (Table 9 and Fig. 10) or fruit (Fig. 13).

DWRM (1 L/ha) is likely to provide excellent resistance to rain wash-off for Kocide sprays targeted at the upper leaf surface of Hort 16A (Table 9). Alternatively, the addition of Du-Wett to concentrate sprays is unlikely to markedly reduce the rainfastness of copper sprays applied to foliage of Hort 16A (Table 10). These adjuvant effects are similar to those reported with a Kocide Opti (1.6 kg/ha) application to Hayward leaves, followed by a brief heavy rain event (Gaskin 2011). In that study, mean deposits on the upper and lower leaf surfaces pre-rain were 48 and 94 ppm, respectively. Mean post-rain (4 mm of a heavy 16 mm/h rain) residues were lower than those measured after 50 mm rain (at 10 mm/h intensity) in this current study. Upper leaf residues were reduced by 82% vs 60%, and lower leaf residues reduced by 88 vs 71% for the previously reported and current studies, respectively. This indicates that copper residues will depend not only on total rain but also on intensity. As expected, heavy rain events will reduce copper residues faster than less intense rainfall.

TABLE 9: Copper residues (ppm) from adjuvant sprays remaining on Hort 16A foliage and fruit after increasing rain events (all treatments contain Kocide Opti 1.3 kg/1000 L/ha)

Tmt #	Adjuvant treatment	Target surface	Rain applied (mm total) 0	25	50
1	DWRM 700 ml	Upper leaf	24	21	14
		Lower leaf	75	33	24
		Fruit	*1.7*	*1.7*	*2.3*
2	DWRM 1000 ml	Upper leaf	43	38	19
		Lower leaf	65	38	20
		Fruit	*2.3*	*1.6*	*2.0*
3	DW 350 ml	Upper leaf	46	32	15
		Lower leaf	87	32	14
		Fruit	*1.6*	*2.0*	*1.8*
4*	Nil (dilute spray)	Upper leaf	29	10	7
		Lower leaf	84	39	18
		Fruit	*2.2*	*2.3*	*2.6*
	Nil (Blank)	foliage	2.9	-	-
		fruit	1.3	-	-

*this data is extracted from Study 2. This spray was applied in 2000 L/ha and not 1000 L/ha.

TABLE 10: Copper residues (as % of initial deposits) from adjuvant sprays remaining on Hort 16A foliage and fruit after increasing rain events (all treatments contain Kocide Opti at 1.3 kg/1000 L/ha)

Tmt #	Adjuvant treatment	Target surface	Rain applied (mm total) 0	25	50
1	DWRM 700 ml	Upper leaf	100	88	58
		Lower leaf	100	44	32
		Fruit	*100*	*100*	*135*
2	DWRM 1000 ml	Upper leaf	100	88	44
		Lower leaf	100	58	31
		Fruit	*100*	*70*	*87*
3	DW 350 ml	Upper leaf	100	70	33
		Lower leaf	100	37	16
		Fruit	*100*	*125*	*112*
4*	Nil (dilute spray)	Upper leaf	100	34	24
		Lower leaf	100	46	21
		Fruit	*100*	*105*	*118*

*this data is extracted from Study 2. This spray was applied in 2000 L/ha and not 1000 L/ha.

Hayward foliage and fruit

The post-rain residue values and trends on Hayward upper leaf surfaces (Table 11 & Fig. 11) were similar to Hort 16A for all three adjuvant sprays. Initial deposits on the lower leaf surfaces were lower than for Hort 16A, but residues were similar on both varieties after 50 mm rain (Table 11 & Fig. 12). Adjuvants had little effect on residues on fruit, either pre- or post-rain (Table 11 & Fig. 14). DWRM provided little rainfastening benefit relative to the dilute Kocide spray without adjuvant on Hayward foliage. On a positive note, as seen on Hort 16A DW added to concentrate sprays maximised initial deposits and is unlikely to markedly reduce the rainfastness of copper sprays applied to Hayward (Table 12).

TABLE 11: Copper residues (ppm) from adjuvant sprays remaining on Hayward foliage and fruit after increasing rain events (all treatments contain Kocide Opti at 1.3 kg/1000 L/ha)

Tmt #	Adjuvant treatment	Target surface	Rain applied (mm total) 0	25	50
1	DWRM 700 ml	Upper leaf	22	14	11
		Lower leaf	36	26	13
		Fruit	*1.8*	*2.7*	*1.9*
2	DWRM 1000 ml	Upper leaf	43	39	16
		Lower leaf	56	34	16
		Fruit	*2.1*	*1.6*	*1.9*
3	DW 350 ml	Upper leaf	49	19	17
		Lower leaf	69	27	15
		Fruit	*2.0*	*2.0*	*2.0*
4*	Nil (dilute spray)	Upper leaf	39	19	11
		Lower leaf	56	29	22
		Fruit	*1.8*	*1.9*	*1.6*
	Nil (Blank)	foliage	2.9	-	-
		fruit	1.3	-	-

*this data is extracted from Study 2. This spray was applied in 2000 L/ha and not 1000 L/ha.

TABLE 12: Copper residues (as % of initial deposits) from adjuvant sprays remaining on Hayward foliage and fruit after increasing rain events (all treatments contain Kocide Opti at 1.3 kg/1000 L/ha)

Tmt #	Adjuvant treatment	Target surface	Rain applied (mm total) 0	25	50
1	DWRM 700 ml	Upper leaf	100	64	50
		Lower leaf	100	72	36
		Fruit	*100*	*150*	*106*
2	DWRM 1000 ml	Upper leaf	100	91	37
		Lower leaf	100	61	29
		Fruit	*100*	*76*	*90*
3	DW 350 ml	Upper leaf	100	39	35
		Lower leaf	100	39	22
		Fruit	*100*	*100*	*100*
4*	Nil (dilute spray)	Upper leaf	100	49	28
		Lower leaf	100	52	39
		Fruit	*100*	*106*	*89*

*this data is extracted from Study 2. This spray was applied in 2000 L/ha and not 1000 L/ha.

CONCLUSIONS

- Kocide is a very "sticky" formulation and adjuvants are unlikely to markedly increase or reduce its resistance to rain wash-off.
- Du-Wett addition (350 ml/ha) to 2x concentrate sprays will not reduce the rainfastness of Kocide, but its effect at higher concentrations is unknown.
- Du-Wett Rainmaster (1 L/ha) can improve the longevity of copper residues in ≤ 50 mm rain on easy-to-wet upper leaf surfaces, but the adjuvant has little rainfastening effect on residues on the hairy lower surfaces.
- Du-Wett and Du-Wett Rainmaster will provide more thorough leaf coverage of concentrate copper sprays than will dilute sprays without adjuvant addition. The premise is that coverage equals protection.
- Adjuvants had little or no effect on residues on fruit.

ACKNOWLEDGEMENTS

Thanks to Plant and Food Research (Te Puke), Leighton Oates and Phil Leppard for allowing us to collect fruit and/or foliage from their orchards. Scion Nursery gave us access to their rain-making facility. Etec Crop Solutions supplied Du-Wett and Du-Wett Rainmaster adjuvants. Alison Forster, Rebecca van Leeuwen, and Justin Nairn (PPC_{NZ}) provided technical assistance.

REFERENCES

Gaskin RE, 2011. Rainfastness of Kocide Opti sprays applied to Hayward kiwifruit foliage. Report to Etec Crop Solutions Ltd, March 2011. 4 pp.

APPENDIX

Data from Tables 3- 11 presented as TRENDLINE graphs.
(Refer back to tables for actual data)

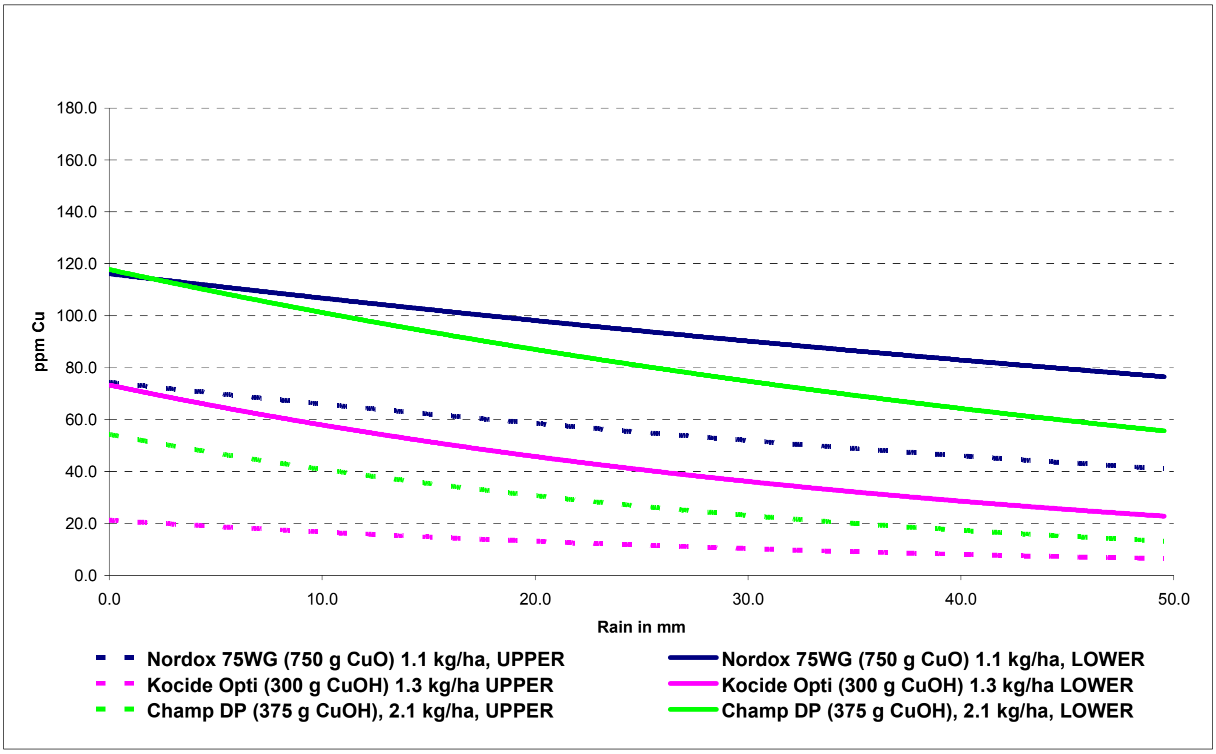

Fig. 3: Post-rain residue trends (ppm) of three copper sprays applied to <u>upper and lower leaf surfaces of Hort 16A</u> foliage (data from Table 3)

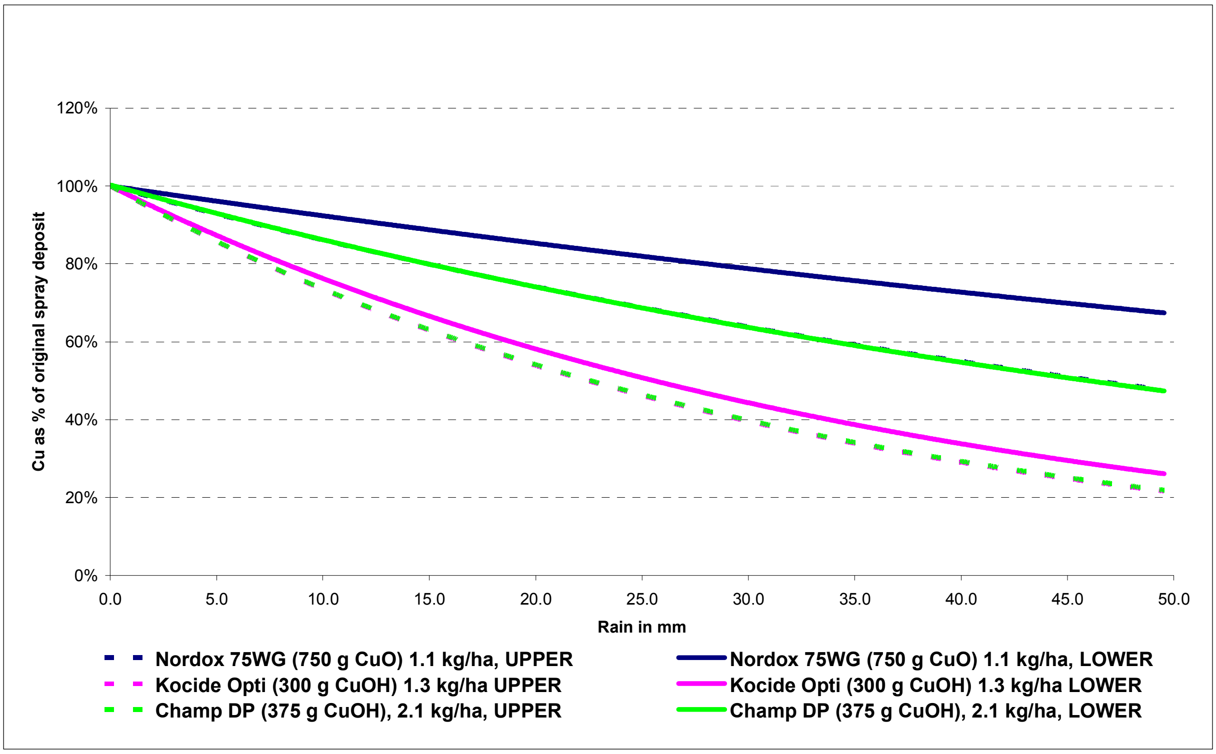

Fig. 4: Post-rain residue trends (as % of initial deposits) of three copper sprays applied to <u>upper and lower leaf surfaces of Hort 16A</u> foliage (data from Table 4)

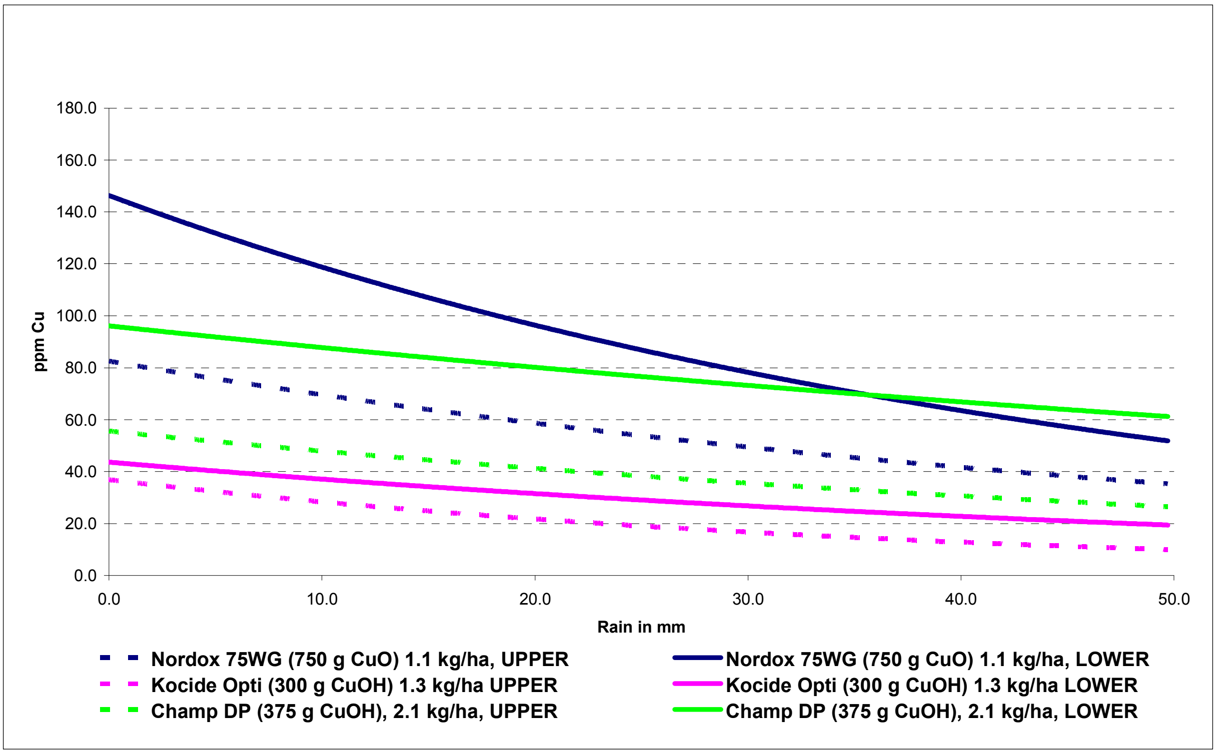

Fig. 5: Post-rain residue trends (ppm) of three copper sprays applied to <u>upper and lower leaf surfaces of Hayward</u> foliage (data from Table 5)

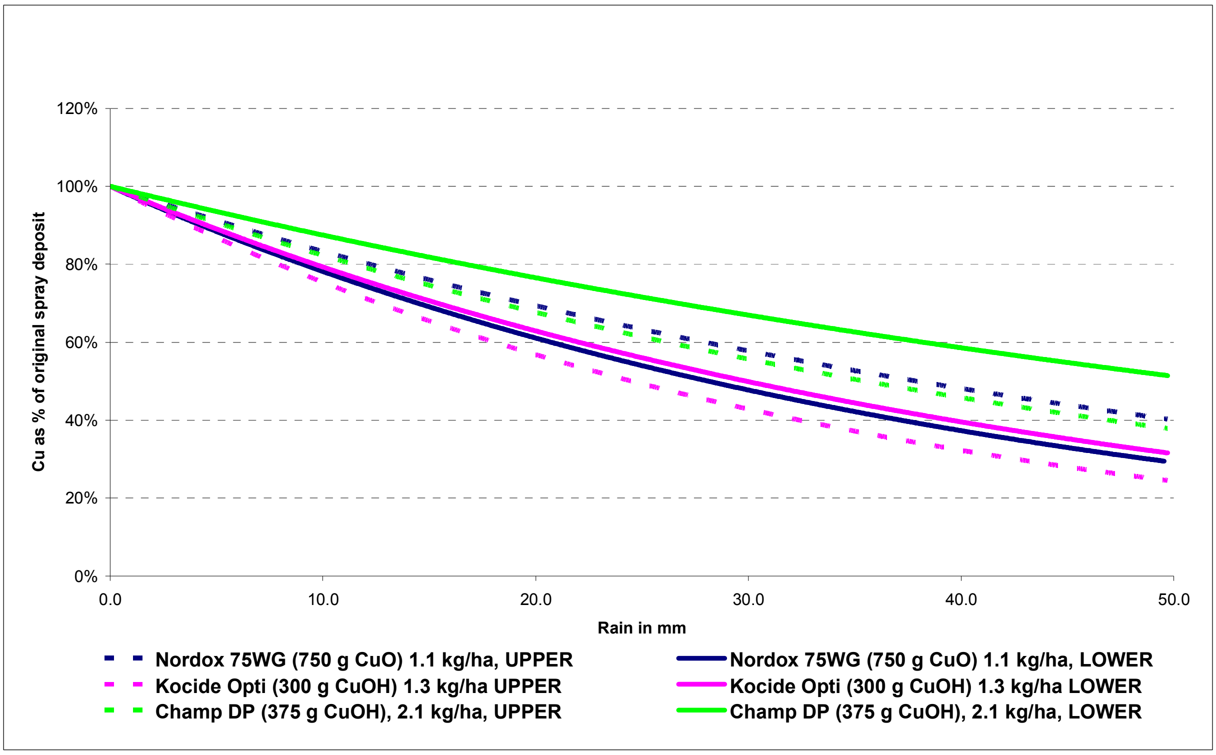

Fig. 6: Post-rain residue trends (as % of initial deposits) of three copper sprays applied to <u>upper and lower leaf surfaces of Hayward</u> foliage (data from Table 6)

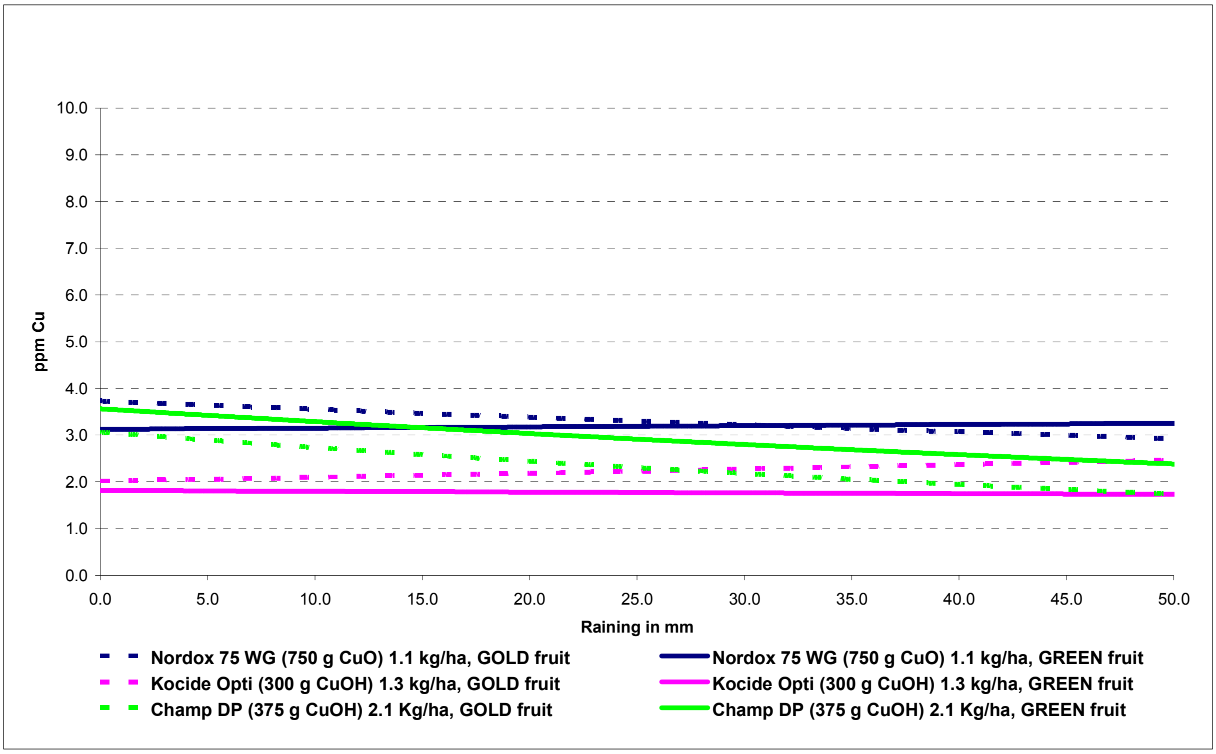

Fig. 7: Post-rain residue trends (ppm) of three copper sprays applied to <u>Hort 16A and Hayward fruit</u> (data from Table 7)

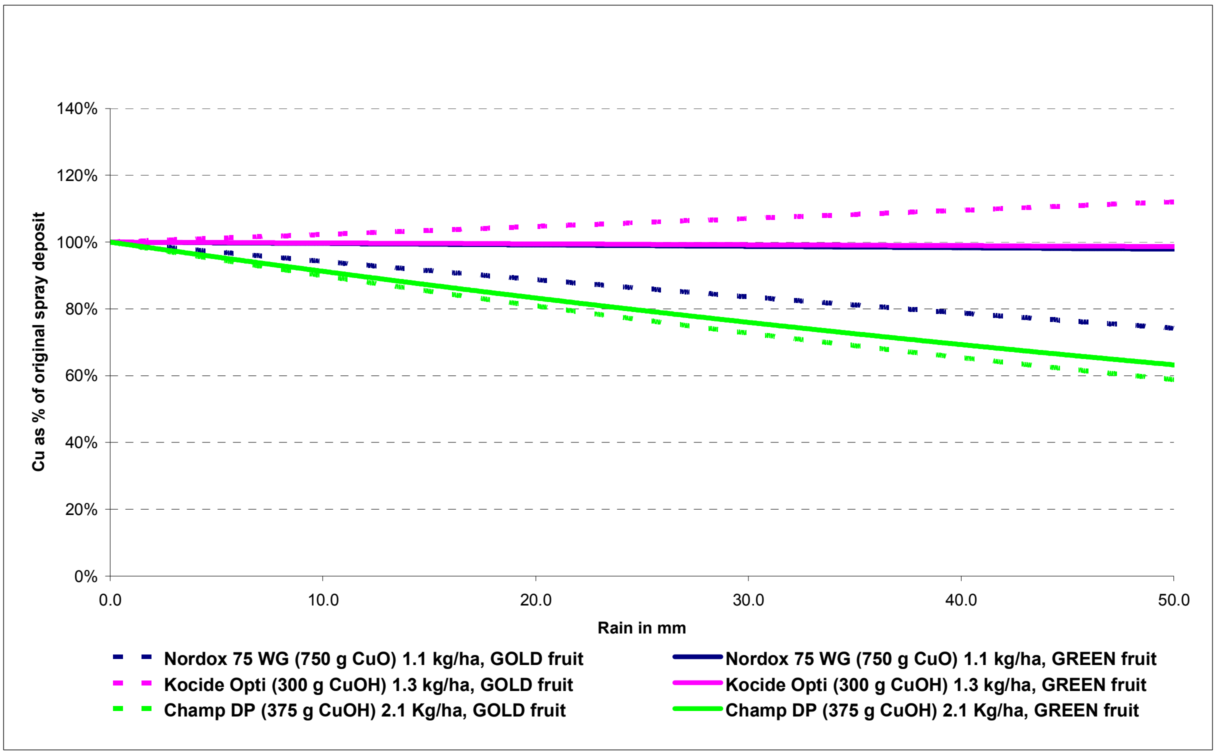

Fig. 8: Post-rain residue trends (as % of initial deposits) of three copper sprays applied to <u>Hort 16A and Hayward fruit</u> (data from Table 8)

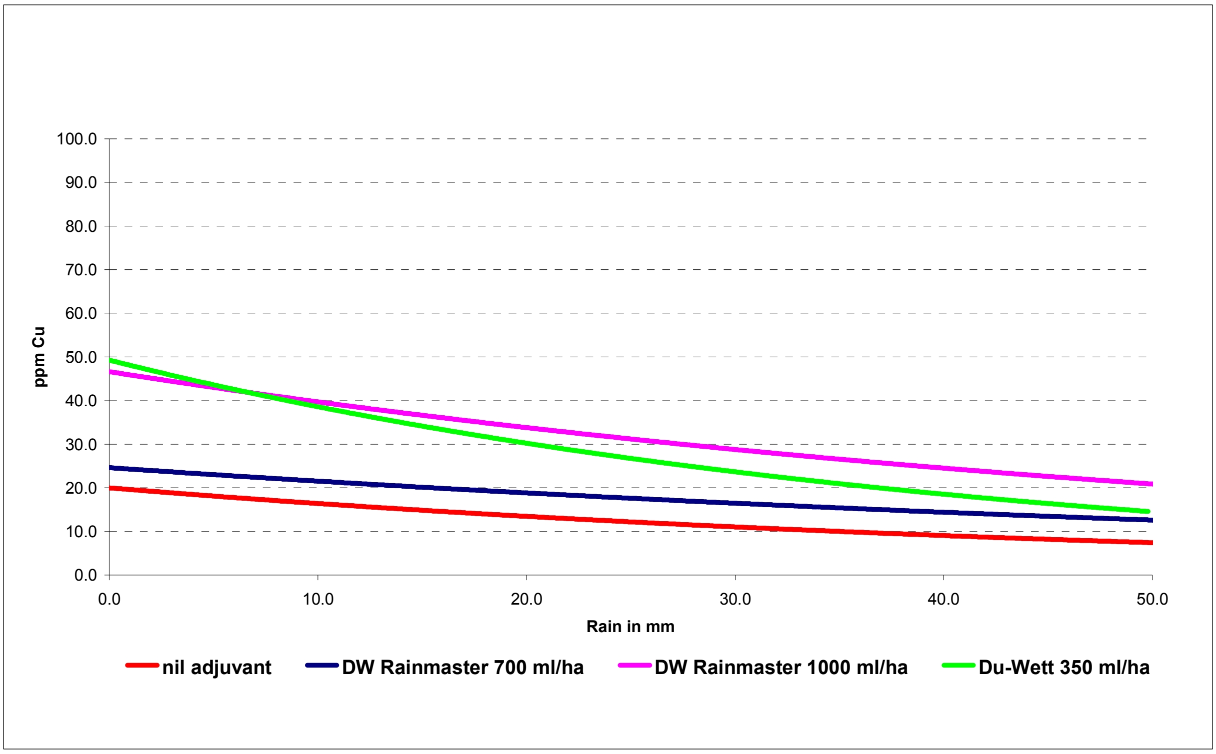

Fig. 9: Post-rain copper residue trends (ppm) of adjuvant sprays applied to <u>Hort 16A upper leaf</u> surface (data from Table 9)

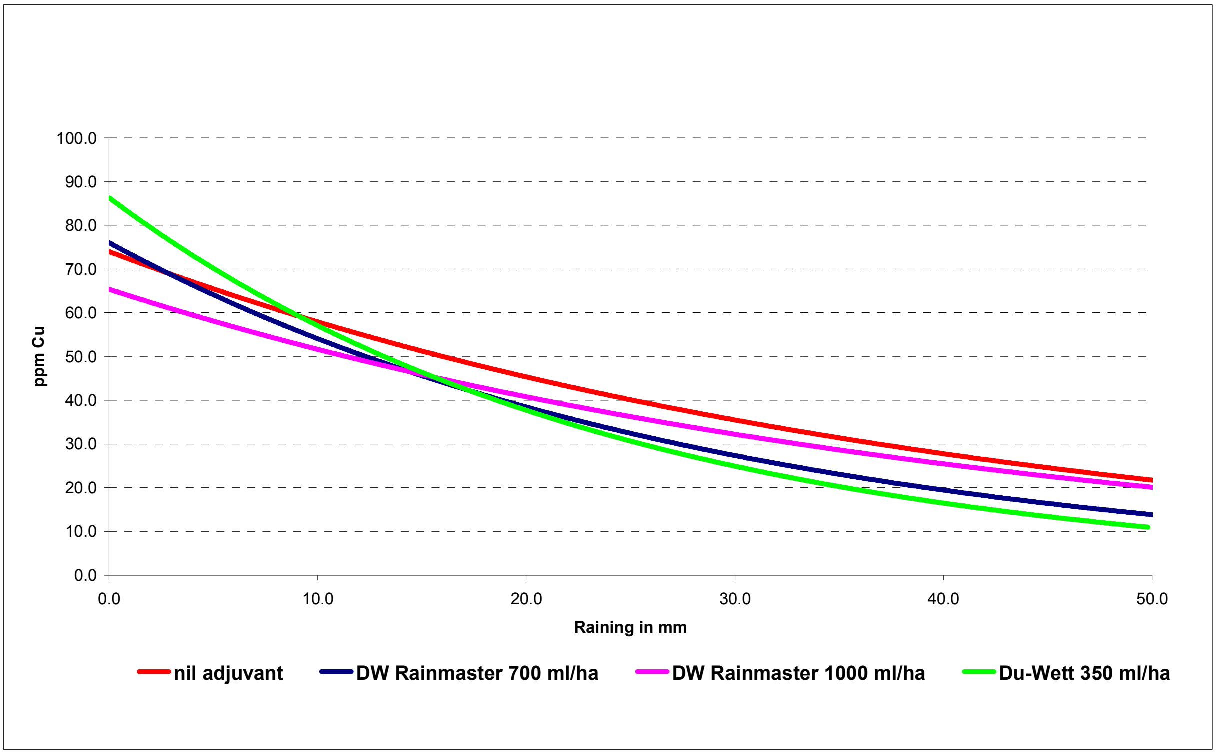

Fig. 10: Post-rain copper residue trends (ppm) of adjuvant sprays applied to <u>Hort 16A lower leaf</u> surface (data from Table 9)

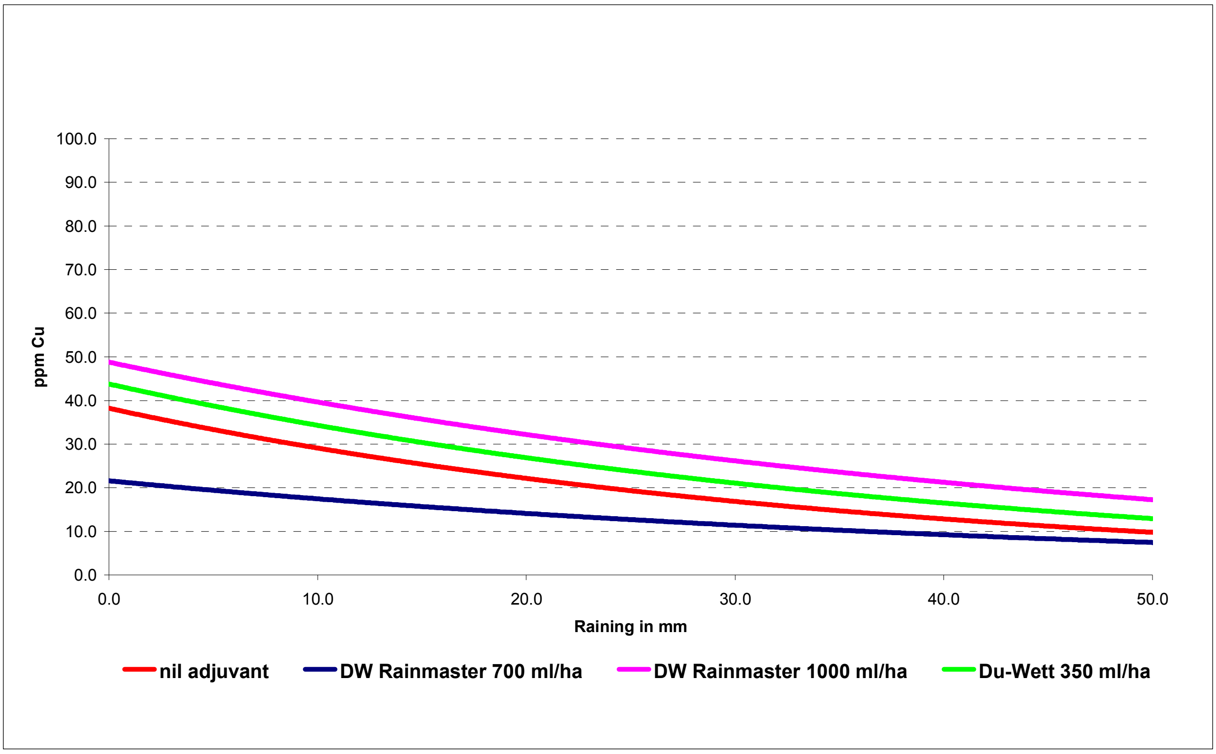

Fig. 11: Post-rain copper residue trends (ppm) of adjuvant sprays applied to <u>Hayward upper leaf</u> surface (data from Table 11)

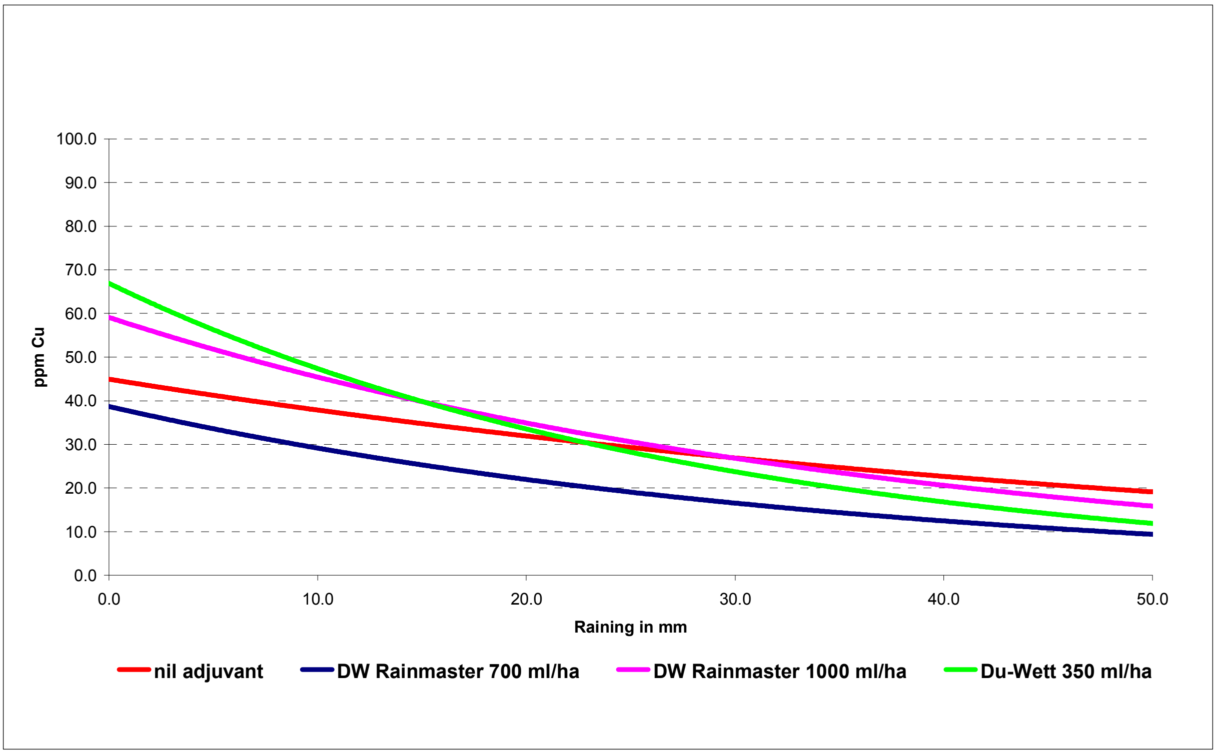

Fig. 12: Post-rain copper residue trends (ppm) of adjuvant sprays applied to <u>Hayward lower leaf</u> surface (data from Table 11)

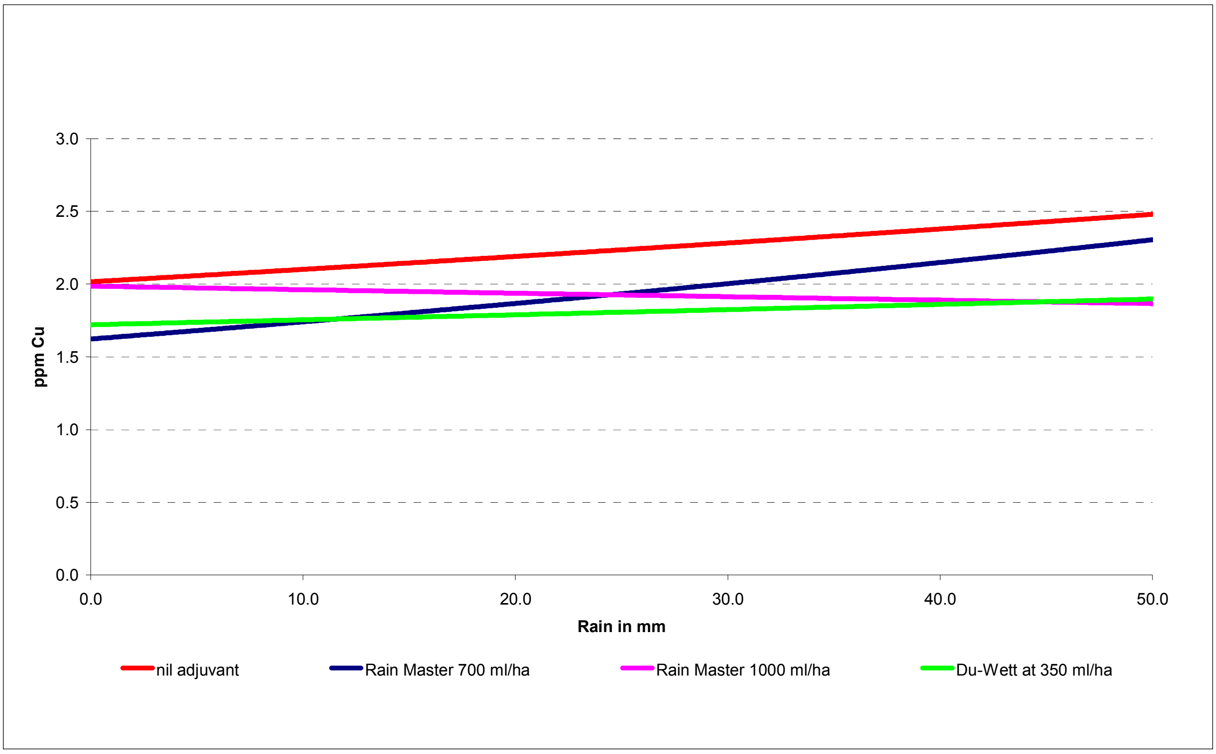

Fig. 13: Post-rain copper residue trends (ppm) of adjuvant sprays applied to <u>Hort 16A fruit</u> (data from Table 9)

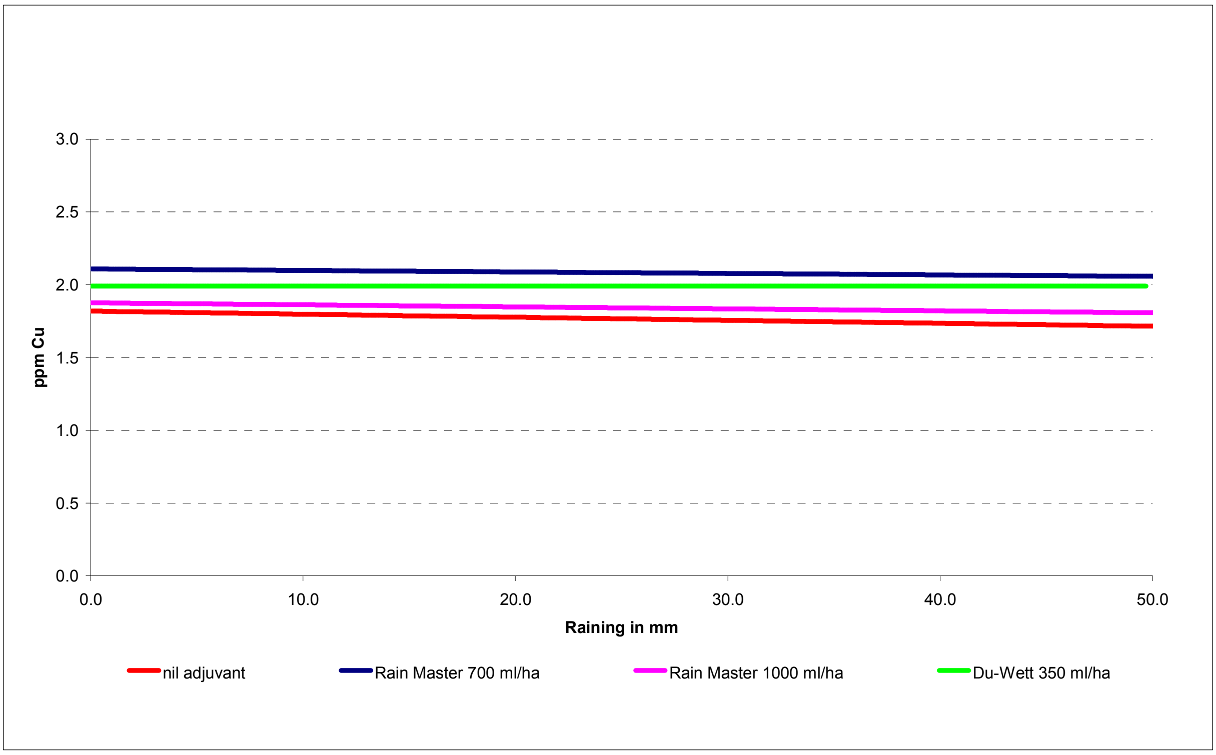

Fig. 14: Post-rain copper residue trends (ppm) of adjuvant sprays applied to <u>Hayward fruit</u> (data from Table 11)

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