Safety of Copper Products on Kiwifruit

Report Prepared For
NuFarm Limited and HortiGro Limited

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1.0 Executive Summary

Seventeen different Copper treatments were applied to both Hayward and Hort16A canopies, from bud break to fruit set, to evaluate the effect of the treatments on leaf and fruit health, by comparison with an untreated control.

Treatments were not replicated so conclusions about individual products relative to other products should be considered tenuous.

Application rates were equalized across all products, to apply either 40 or 60g Copper/100L, with the exception of treatment 18. The intention was to compare effects on vines, for an equivalent amount of applied Copper, across the range of treatments.

It is important to note that the application rates of 40 or 60g Copper/100L are not necessarily the label rates for the commercial products used. In fact, some of the products in the trial do not have label rates for application on kiwifruit.

Treatment 18 was Liquicop at the recommended summer rate of 2L product/ha, which results in 12 – 26g Copper/100L, for water rates ranging between 700 – 1500L/ha. This is below the 40 and 60g/100L rates tested as other Liquicop treatments in this trial

Five applications were made of each product on Hort16A and six on Hayward. Plot size was one bay per treatment.

For Hort16A, the intervals between applications of Champ DP and Selecta Disperss at 40 and 60g Copper/100L were different from the other Copper treatments, because these two products were not available at the start of the trial.

For Hayward, all treatments were applied at each application date.

All products were applied using a hand held pressure sprayer and Driftstop added at 100ml/100L to ensure good wetting and spreading, without the risk of either excess runoff or stomatal uptake that could occur when using such a sprayer.

Inspection was undertaken for any visual signs of foliage effects on four occasions through the application period, and for fruit effects after the final application of treatments, on 27 December 2012.

Leaf and fruit scoring was undertaken using a 1-10 scale, with 1 meaning no effects and 10 meaning severely affected.

It takes time and a number of applications for phytotoxic effects to become evident.

On Hort16A first phytotoxic effects, at the lower end of the scale, were observed after the second or third treatment applications had been made, about 32 - 34 days after the application programme commenced.

On Hayward, no leaf phytotoxic effects were seen after the first four applications of all products and 27 days from first application. Effects were first seen at assessment after 5 applications of all products and 45 days from first application. Most treatments were starting to show some phytotoxic effects at the lower end of the scale.

Further applications increased the leaf phytotoxic effects.

For Hort16A, at the final assessment, most affected treatments were Nordox 75WG, Liquicop and Champ DP at 40 and 60g/100L, with scores of 7 - 9 out of 10. For Hayward, at the final assessment, the most affected treatments were the Champ DP, Champ Flo, Champ WG, Cuprofix Disperss, Nordox 75WG and Liquicop, at 40 and 60g/100 L, all had reasonable levels of phytotoxicity, at 6 or 7 out of 10 on the rating scale.

For Hort16A, least affected treatments were TriBase Blue, Champ Flo, Champ WG all at 40g/100L and Liquicop at 2l/ha, with scores of 5 out of 10. Selecta Disperss at 40 and 60g/100L had the lowest leaf phytotoxicity scores of any product after five applications at 4 out of 10.

For Hayward, the lowest levels of leaf phytotoxicity were for TriBase Blue at 40g/100L and Liquicop at 2L/ha, both with score of 3 out of 10.

These leaf phytotoxicity results should not be relied on to predict crop safety as they are derived from single unreplicated treatments only and do not consider the possible consequential effects of leaf damage on yield and fruit characteristics.

Fruit marking also occurred on both Hort16A and Hayward. It is likely that the inclusion of Driftstop in the post bloom applications resulted in better spray coverage on fruit skins and slower drying, to increase the phytotoxic effects of Copper ions on the developing fruit skin.

It is also possible that there is a sensitive window for skin damage resulting from Copper application an undefined period after fruit set.

On Hayward, fruit marking completely disappeared and was not a factor causing reject fruit at grading.

On Hort16A, fruit marking diminished but was still present at harvest.

Key points of the Hort16A reject fruit analysis at harvest are

- For any product, the percentage reject due to phytotoxicity was higher at the 60g than the 40g/100L rate for that product
- Six treatments had very high percentage reject due to phytotoxicity
- Of these six treatments, four of them, the 40g and 60g/100L rates of both Champ DP and Selecta Disperss were applied three times post bloom, compared with either once or not at all post bloom for the lower scoring reject rate treatments
- In this trial, more applications early post bloom resulted in higher fruit phytotoxicity
- Of the six treatments, the 40g and 60g/100L rates of Liquicop, well above manufacturer recommendations, resulted in the highest level of fruit phytotoxicity
- While the absolute amount of copper applied in Liquicop at 40g and 60g/100L was the same as for other products, there is a factor or factors associated with this product which increased the phytotoxicity damage. This might be related to the much smaller average particle size of Liquicop
- Liquicop applied at the recommended rate of 2L/ha caused a low percentage reject due to phytotoxicity, for products applied post bloom
- Nordox at 40g/100L resulted in no percentage reject due to phytotoxicity

This trial was not established to quantify the effects of leaf phytotoxicity on yield, or size or any aspect of fruit quality. The degree of effect of copper applications on leaves and the consequences of those effects deserve further consideration.

2.0 Introduction

Copper products are essential to the 2011 Zespri Crop Protection Programme for Psa disease control.

A range of copper formulations was included on the Zespri Crop Protection Programme, with only limited information about their safety in a multiple application programme. The risk of phytotoxicity increases with

- Low water pH
- Application in association with other products (especially acidic ones)
- Cool and slow drying conditions
- High number of applications
- Using high water rates and super spreaders combined
- Variety – differing varieties may show varying sensitivity at different times

2.0 Objectives

To evaluate a range of copper products and formulations on both Hayward and Hort16A in a multiple application programme for phytotoxic effects.

Applications were made at approximately 10 day intervals, modified by weather available windows for spraying, from green tip to fruit set.

3.0 Materials and Methods

The trial programme was undertaken on Hayward and Hort16A available at the same site.

3.1 Site Information

Table 1	**Hayward and Hort16A Site Information**
Location	G and A Zimmerman, 94 Snodgrass Road, Te Puna, Tauranga Phone (07) 5524790; 027 4996292 KPIN 4619; alisona@hotmail.com
Site Details	Blocks - Conventional mature, even growth habit Hayward and Hort16A, Average Performing Blocks, Irrigated. Managed by GroPlus Post harvest service supplier is MPAC
Structures	Pergola trained
Spacing	Hort16A 3.3m x 5.0m; Hayward 4.5m x 5.5m
Water rate	Bud break - fruit set 700 - 1000L/ha to spray to wet, using fine droplets to achieve full coverage
Application	Treatments as below
Sprayer	5L multi-purpose hand-held pressure sprayers with fine nozzle

3.2 Treatments/ Plot Number

Plots were not replicated. It was considered that multiple applications of the same product on the same plot would indicate whether or not phytotoxic effects occur and accumulate.

Plot size was one bay per treatment.

There were 18 treatments each for Hayward and Hort16A, including an untreated control.

Refer Appendix 1: Plot Layout

The trial area was defined by hazard tape tied at

- Every row end of the block
- Every row in the block, at the end of one bay beyond where last treatments were applied, with tape hanging down in the row centre

Table 2: Summary of Treatments

No.	Treatment	Copper Concentration	unit/L	product/100L	Copper g or ml /100L
1	UTC	-	-	-	-
2	TriBase Blue	190	g	210	40
3	TriBase Blue	190	g	316	60
4	Champ DP	375	g	107	40
5	Champ DP	375	g	160	60
6	Champ Flo	334.5	ml	119	40
7	Champ Flo	334.5	ml	179	60
8	Champ WG	500	g	80	40
9	Champ WG	500	g	120	60
10	Cuprofix Disperss	200	g	200	40
11	Cuprofix Disperss	200	g	300	60
12	Selecta Disperss	200	g	200	40
13	Selecta Disperss	200	g	300	60
14	Nordox 75WG	750	g	53	40
15	Nordox 75WG	750	g	80	60
16	Liquicop	92.8	ml	431	40
17	Liquicop	92.8	ml	646	60
18	Liquicop	92.8	ml	200 (2L/ha)	18.6

Product rates were selected to compare the effect of Copper applications at equal amounts of Copper in the spray solution. For each Copper product tested, product was applied at the equivalent of 40 and 60g Copper/100L.

All products were applied with Driftstop at 100ml/100L. This gave good wetting and spreading without the risk of excess runoff or stomatal uptake that could occur with an organosilicone adjuvant when using a knapsack sprayer.

Treatments were pre-measured off site in an appropriate facility by the Applicator who holds current GrowSafe and Approved Handler certificates.

Application was planned for and achieved in suitable conditions, except for the final product applied on 15 October 2011.

Application details were recorded as per the table below.

Table 3: Application Details

Date	Treatment	Water Rate L/ha	Weather	Temp °C	Wind

8/9/11	2 -17 except 4,5,12,13	700	fine	20	calm to N drift
20/9/11	2 -18 except 4,5,12,13	700	fine	18	calm to swirling eddies
28/9/11	2 -18	700	fine	19	calm to light NE
15/10/11	2 -18	gold 1000 green 700	fine until 3:50 when a short heavy downpour occurred immediately finishing treat 17, both gold & green. Treat 18 sprayed onto saturated foliage of both	22	mostly calm, occasional WNW
24/10/11	2 - 18	700	fine	20	calm
3/11/11	2 – 18	700	fine	21	calm to gusty WNW up to 13 kph
11/11/11	green 2 – 18 gold 4, 5, 12, 13	both 1000	fine	22	light NE to calm
22/11/11	green 2 – 18 gold 4, 5, 12, 13	both 1000	overcast	21	W
9/12/11	green 2 – 18 gold all except 10, 11	both 1500	overcast to fine	25	light swirling eddies all directions

Applications commenced as soon as products were supplied. The first two applications on the earlier variety Hort16A did not include Champ DP and Selecta Disperss, as the products were not available.

The result was a pause in applications on most Hort16A treatments to allow for treatments 4,5,12 and 13 to be caught up to the same number of applications as all other treatments, once Selecta Disperss and Champ DP were available.

Table 4: Hort16A Application and Intervals in Relation to Growth Stage

Application Dates	Interval days excl 4,5,12,13	Days from 1st application excl 4,5,12,13	Interval days 4,5,12,13	Days from 1st application 4,5,12,13	Growth Stage
8/09/2011		0	0		early spring growth
20/09/2011	12	12	0		mid spring growth
28/09/2011	8	20	0	0	mid spring growth
15/10/2011	17	37	17	17	pre bloom
11/11/2011			27	44	post bloom
22/11/2011			11	55	fruit expansion
9/12/2011	55	92	17	72	fruit expansion

For Hayward, all treatments were applied at all application dates.

Table 5: Hayward Application and Intervals in Relation to Growth Stage

Application Dates Hayward	Interval days between applications	Interval days from 1st application	Growth Stage
15/10/2011		0	early spring growth
24/10/2011	9	9	mid spring growth
3/11/2011	10	19	mid spring growth
11/11/2011	8	27	pre bloom
22/11/2011	11	38	early bloom
9/12/2011	17	55	post bloom

No other applications for PSA protection were made within the trial area, from bud break to post bloom.

5.0 Assessments

Phytotoxicity
Inspection was undertaken for any visual signs of foliage effects on four occasions through the application period. Inspection was also undertaken for any visual signs of foliage and fruit effects after the final application of treatments, on 27 December 2012.

Scoring was undertaken on a 1-10 scale, with 1 meaning no effects and 10 meaning leaves severely affected as a result of phytotoxic effects. **Refer Appendices 2 and 3**

Table 6: Leaf Phytotoxicity Scoring

Score	Effect
1	**no effects**
2	**very light lines**
3	**light lines**
4	**dark lines**
5	**hatching**
6	**cross hatching**
7	**dark cross hatching**
8	**light necroses**
9	**dark necroses**
10	**widespread dark necroses**

Fruit was also assessed once for phytotoxic effects on 27 December 2011. Scoring was undertaken on a 1-10 scale, with 1 meaning no effects and 10 meaning fruit severely affected as a result of phytotoxic effects.

Spray Mix pH
Spray solution pH can be a contributing factor to Copper plant phytotoxicity. The lower the solution pH, the greater the availability of Copper ions. Plant tissue damage can then occur as Copper ions are available in higher concentration, than for a near neutral or alkaline pH.

Spray solution pH was measured on two occasions, by collecting sprayate when each spray solution was freshly prepared and the water source itself. Laboratory testing of pH was undertaken by Plus Group on the first occasion and Hill Laboratories on the second occasion.

Leaf Copper Deposits
The leaf Copper levels were measured on one occasion. For Hort16A, twenty leaves per plot were collected. A 25 cm^2 area was cut from the mid-section of each leaf. Each cut leaf square was washed in solution to remove deposited Copper. All washings from each plot were amalgamated to create one composite sample per plot.

Each composite sample was analysed for Copper, using 5ml extracted volume per sample. The result in mg/L was then able to be calculated as µg/square centimetre of leaf area, based on the leaf area sampled.

Fruit Assessment

At harvest, each bay was separately picked into its own bin. Each bin was subsequently graded and packed over the standard packhouse equipment at MPAC, Mount Maunganui. The pack results for each treatment were therefore reported separately for each treatment.

For each treatment, all of the reject and undersize fruit were collected and counted to determine the total number of reject fruit per treatment. A combined undersize plus reject sample was assessed for phytotoxicity for each treatment.

Data collected included gross fruit weight, reject weight, number of trays packed, average count size and number of reject fruit per 30 fruit sample due to fruit phytotoxicity.

6.0 Results

6.1 Hort16A

Table 6: Hort16A Leaf Phytotoxicity Scores

Treatment No.	Treatment	Score						No. Apps Post Bloom
		20/09/2011	26/09/2011	10/10/2011	01/11/2011	27/12/2011	27/12/2011	
		leaf	leaf	leaf	leaf	leaf	fruit	
1	UTC	1	1	1	1.0	1	1	0
2	TriBase Blue	1	1	2	3.0	5	2	1
3	TriBase Blue	1	1	1	2.5	6	2	1
4	Champ DP	1	1	1	1.5	7	3	3
5	Champ DP	1	1	1	2.0	8	4	3
6	Champ Flo	1	1	2	5.0	5	2	1
7	Champ Flo	1	1	1	3.5	6	3	1
8	Champ WG	1	1	1	1.5	5	2	1
9	Champ WG	1	1	1	4.0	6	3	1
10	Cuprofix Disperss	1	1	1	4.5	6	2	0
11	Cuprofix Disperss	1	1	2	4.5	6	2	0
12	Selecta Disperss	1	1	1	1.0	4	2	3
13	Selecta Disperss	1	1	1	1.0	4	3	3
14	Nordox 75WG	1	1	1	7.0	8	3	1
15	Nordox 75WG	1	1	1	7.0	8	3	1
16	Liquicop	1	1	3	4.5	8	3	1
17	Liquicop	1	1	2	4.5	9	4	1
18	Liquicop	1	1	1	3.5	5	2	1

For all treatments in the earlier group of products applied, including TriBase Blue, Champ Flo, Champ WG, Cuprofix Disperss, Nordox 75WG and Liquicop, no leaf phytotoxic effects were seen after the first two applications.

First phytotoxic effects, at the lower end of the scale, were observed on 10 October 2011, after the third treatment applications had been made on 28 September 2011 and 32 days after the application programme commenced on 8 August 2011.

Treatments including TriBase Blue at 40g/100L, Champ Flo at 40g/100L, Cuprofix Disperss at 60g/100L and Liquicop at 40 and 60g/100L all showed slight phytotoxic effects at 10 October 2011.

Treatments including TriBase Blue at 60g/100L, Champ Flo at 60g/100L, Champ WG at 40 and 60g/100L, Cuprofix Disperss at 40g/100L, Nordox 75WG at 40 and 60g/100L and Liquicop at 2L/ha did not show phytotoxic effects at 10 October 2011.

At the next assessment on 1 November 2011 all products at either rate were showing phytotoxic effects to varying degrees.

Nordox 75WG at both 40 and 60g/100L showed the most advanced effects with a score of 7, followed by both Cuprofix Disperss and Liquicop at 40 and 60g/100L, having phytotoxicity scores of 4.5.

By the final assessment on 27 December 2011 and after the fifth treatment application, the phytotoxic effects had worsened on all treatments.

Most affected were the Nordox 75WG, Liquicop and Champ DP treatments at 40 and 60g/100L, with scores of 7 - 9 out of 10. Although not part of the scoring system, it was noticeable that on the canopies treated with Nordox 75WG and Liquicop treatments at 40 and 60g/100L, there was a significant amount of annual growth which had short internodes and had terminated at a shorter cane length than for other treatments and the untreated control.

Least affected were TriBase Blue, Champ Flo, Champ WG all at 40g/100L and Liquicop at 2l/ha, with scores of 5 out of 10.

For all treatments in the later group of products applied, first leaf phytotoxic effects, at the lower end of the scale, were seen on the 1st November for Champ DP at 40 and 60g/100L after two applications and 34 days after first application. No phytotoxic effects were observed on Selecta Disperss at 40 and 60g/100L at that time.

By the final assessment on 27 December 2011 and after the fifth treatment applications, the phytotoxic effects had worsened for Champ DP at 40 and 60g/100L and had become evident on Selecta Disperss at 40 and 60g/100L.

Selecta Disperss at 40 and 60g/100L had the lowest leaf phytotoxicity scores of any product after five applications

Fruit was assessed for phytotoxic effects once on 27 December 2012. At that time, Champ DP and Selecta Disperss at 40 and 60g/100L had been applied three times to fruitlets. All other treatments had been applied once to fruitlets.

The exception was Cuprofix Disperss, which was not applied for the fifth application, and therefore not on fruitlets at all as the proprietor, NuFarm Ltd did not consider this product to be a safe in season choice on fruitlets.

All fruit showed some phytotoxic effects including treatments 10 and 11,

Cuprofix Disperss at 40 and 60g/100L, where the product treatments were not actually applied to fruitlets. The effects observed were spotting and streaking as per the illustration right.

Figure 1: Hort16A Fruit Marking

Effects were most pronounced on Champ DP and Liquicop at 60g/100L.At harvest, there was significant marking on Hort16A fruit which had not dissipated.

Table 7: Hort16A Reject Assessment due to Phytotoxicity

No.	Treatment	Copper	Rejects due to Cu (30 fruit sample)		No. Applications post bloom
		g or ml/100L	Fruit No.	%	
1	UTC	-	0	0	-
2	TriBase Blue	40	5	17	1
3	TriBase Blue	60	16	53	1
4	Champ DP	40	12	40	3
5	Champ DP	60	25	83	3
6	Champ Flo	40	11	37	1
7	Champ Flo	60	18	60	1
8	Champ WG	40	10	33	1
9	Champ WG	60	18	60	1
10	Cuprofix Disperss	40	1	3	0
11	Cuprofix Disperss	60	2	7	0
12	Selecta Disperss	40	21	70	3
13	Selecta Disperss	60	25	83	3
14	Nordox 75WG	40	0	0	1
15	Nordox 75WG	60	11	37	1
16	Liquicop	40	24	80	1
17	Liquicop	60	30	100	1
18	Liquicop	2L/ha	3	10	1

6.2 Hayward

Table 8: Hayward Leaf Phytotoxicity Scores

Treatment No.	Treatment	Copper g or ml /100L	Score						No. Apps Post Bloom
			4/11/2011	16/11/2011	29/11/2011	6/12/2011	27/12/2011	27/12/2011	
							leaves	fruit	
1	UTC	-	1	1	1	1	1	1	0
2	TriBase Blue	40	1	1	3	4	3	2	1
3	TriBase Blue	60	1	1	3	4	5	3	1
4	Champ DP	40	1	1	3	3	6	2	1
5	Champ DP	60	1	1	3	6	6	3	1
6	Champ Flo	40	1	1	3	8	6	3	1
7	Champ Flo	60	1	1	2	6	7	5	1
8	Champ WG	40	1	1	2	5	6	3	1
9	Champ WG	60	1	1	1	4	6	3	1
10	Cuprofix Disperss	40	1	1	2	4	6	3	1
11	Cuprofix Disperss	60	1	1	3	5	7	3	1
12	Selecta Disperss	40	1	1	1	2	4	2	1
13	Selecta Disperss	60	1	1	2	3	4	2	1

14	Nordox 75WG	40	1	1	2	3	6	2	1
15	Nordox 75WG	60	1	1	4	5	7	4	1
16	Liquicop	40	1	1	3	4	5	7	1
17	Liquicop	60	1	1	3	7	6	9	1
18	Liquicop	2L/ha	1	1	1	4	3	3	1

For all treatments, no leaf phytotoxic effects were seen after the first four applications of all products and 32 days from first application.

By the next assessment on 29 November, after 5 applications of all products and 45 days from first application, most treatments were starting to show some phytotoxic effects at the lower end of the scale.

The sixth and final treatment applications were made on 9 December 2011. Assessment on 27 December 2011 showed that leaves sprayed with Champ DP, Champ Flo, Champ WG, Cuprofix Disperss, and Nordox 75WG and Liquicop all had reasonable levels of phytotoxicity, at 6 or 7 out of 10 on the rating scale.

The lowest levels of leaf phytotoxicity at that time were for TriBase Blue at 40g/100L and Liquicop at 2L/ha.

Fruit was assessed for phytotoxic effects once on 27 December 2012. At that time, all treatments had been applied once to fruitlets and all treatments showed some phytotoxic effects. Liquicop at 40 and 60g/100L treated fruit had the highest phytotoxicity levels, at scores of 7 and 9, with significant fruit spotting and a noticeable level of red/brown marking on fruit stalks as well as shrivel on some fruit stalks.

Figure 2: Hayward Fruit Marking

Figure 3: Hayward Fruit Stalk Marking and Shrivel

At harvest, only 1 fruit amongst all the reject fruit assessed was considered to be reject because of phytotoxicity.

Spray Solution pH results

The pH results show that none of the solutions resulted in an acid pH which would have enhanced phytotoxic effects. While Hill Laboratories results were consistently higher than Plus Group results, the trends were very similar. The water source pH was alkaline at around pH 8.0. The spray mixes ranged around this pH.

Table 9: Spray Mix pH Results

Treatment No.	Treatment	Copper g or ml /100L	pH – Plus Group	pH – Hill
1	UTC	-	8.07	7.8
2	TriBase Blue	40	7.53	7.9
3	TriBase Blue	60	7.18	7.9
4	Champ DP	40	8.46	9.1
5	Champ DP	60	9.18	9.3
6	Champ Flo	40	8.36	8.2
7	Champ Flo	60	8.1	8.3
8	Champ WG	40	7.69	8.0
9	Champ WG	60	7.01	8.0
10	Cuprofix Disperss	40	6.54	7.7
11	Cuprofix Disperss	60	6.77	7.7
12	Selecta Disperss	40	7.51	8.4
13	Selecta Disperss	60	7.62	8.4
14	Nordox 75WG	40	7.74	7.9
15	Nordox 75WG	60	7.76	8.0
16	Liquicop	40	7.85	8.1
17	Liquicop	60	7.97	8.2
18	Liquicop	2L/ha	7.86	8.0

Leaf Copper Deposits

The table below reports the Copper deposits measured. The results are a snapshot of deposits at one point in time.

Table 10: Leaf Copper Deposits

Treatment No.	Treatment	Copper g or ml /100L	Copper mg/L	Copper µg/cm^2	No. Prior Applications	Most Recent Application days before
1	UTC	-	0.1	0.01	-	-
2	TriBase Blue	40	7.8	0.79	4	38
3	TriBase Blue	60	6.8	0.68	4	38
4	Champ DP	40	12.4	1.25	3	0
5	Champ DP	60	17.0	1.70	3	0
6	Champ Flo	40	3.6	0.36	4	38
7	Champ Flo	60	4.4	0.44	4	38
8	Champ WG	40	3.8	0.39	4	38
9	Champ WG	60	4.1	0.41	4	38
10	Cuprofix Disperss	40	3.4	0.34	4	38
11	Cuprofix Disperss	60	4.6	0.46	4	38
12	Selecta Disperss	40	10.0	1.00	3	0
13	Selecta Disperss	60	18.7	1.85	3	0
14	Nordox 75WG	40	3.3	0.33	4	38

15	Nordox 75WG	60	7.9	0.79	4	38
16	Liquicop	40	5.7	0.57	4	38
17	Liquicop	60	3.8	0.39	4	38
18	Liquicop	2L/ha	2.1	0.21	4	38

Treatments 4,5,11 and 12 had been applied and had dried on prior to sample collection, on the same day that samples were collected. Although only 3 applications of these treatments had been made, by comparison with 4 applications of all other treatments, the immediacy of the most recent application has clearly resulted in the very elevated deposits measured.

The untreated control plot had a very low level of Copper deposit indicating some potential overspray from the adjacent plots.

7.0 Discussion

The trial was intended as a demonstration of relative crop safety of the different products applied at equivalent amounts of copper per 100L.

The leaves assessed were the older leaves in the canopy, so that the cumulative effect of copper applications could be observed.

In general, where leaf phytotoxic effects developed, they were not visible on Hort16A until around 32 – 34 days after first application, by which time 2 or 3 applications had been made.

For Hort16A, the cumulative effect of 5 applications of either Nordox 75WG or Liquicop treatments at 40 and 60g/100L over 92 days from bud break to fruit sizing, resulted in the highest level of leaf phytotoxicity and associated with this, suppression of canopy extension growth on the replacement canes.

Champ DP at 40 and 60g/100L over 72 days from mid spring growth to fruit sizing also approached these levels of leaf phytotoxicity.

It may be that where a canopy is weaker, producing less foliage and with lower leaf density, for whatever reason, multiple applications of copper products might increase the phytotoxic effect of the copper ions on the canopy that is present, simply because there is less surface area dispersing the copper applied.

Fruit damage was evident on all treatments except the untreated control plot and this plot compares similarly with fruit in the same block, outside of the entire trial area, which had also not been treated with any copper products since bud break.

Treatments 10 and 11 had no Cuprofix Disperss applied during or post bloom. Despite this, fruit phytotoxicity was present at very similar levels to other treatments, when assessed in late December 2011.

An informal review of Hort16A plots in February 2012 showed diminution of fruit marking from assessment at 27 December 2011, but the marking was still largely visible.

The marking did not fade to insignificance by harvest. The amount

of fruit affected by phytotoxicity resulted in the packhouse being unable to achieve export packing within specification.

Figure 4: Light (left) and heavy (right) Hort16A fruit phytotoxicity
The entire line of export packed Hort16A fruit across all treatments would have required regrading and repacking to be within specification.

Key points of the reject fruit analysis at harvest are

- For any product, the percentage reject due to phytotoxicity was higher at the 60g than the 40g/100L rate for that product
- Six treatments had very high percentage reject due to phytotoxicity
- Of these six treatments, four of them, the 40g and 60g/100L rates of both Champ DP and Selecta Disperss were applied three times post bloom, compared with either once or not at all post bloom for the lower scoring reject rate treatments
- In this trial, more applications early post bloom resulted in higher fruit phytotoxicity
- Of the six treatments, the 40g and 60g/100L rates of Liquicop, well above manufacturer recommendations, resulted in the highest level of fruit phytotoxicity
- While the absolute amount of copper applied in Liquicop at 40g and 60g/100L was the same as for other products, there is a factor or factors associated with this product which increased the phytotoxicity damage. This might be related to the much smaller average particle size of Liquicop
- Liquicop applied at the recommended rate of 2L/ha caused a low percentage reject due to phytotoxicity, for products applied post bloom
- Nordox at 40g/100L resulted in no percentage reject due to phytotoxicity

For Hayward, 5 applications of treatments were applied over a shorter timeframe of 55 days. It is assumed that the closer average interval between applications might increase the risk of phytotoxic effects.

In fact, the leaf phytotoxicity scores for Hayward were not quite as severe as for Hort16A suggesting that Hayward is more tolerant of Copper applications, at least from an appearance perspective.

Although the assessment timings do not pinpoint when phytotoxic effects became evident on Hayward leaves, effects developed after 27 days and before 45 days from first application and by which time 4 applications had been made. There is some similarity to Hort16A where phytotoxic effects were seen around 32 – 34 days after first application, by which time 2 or 3 applications had been made.

The effects on canopy appear different between Hayward and Hort16A, as shown in the attached Appendices 2 and 3.

An informal review of Hayward plots in February 2012 showed a complete diminution of fruit marking from assessment at 27 December 2011, to the extent that the marking was no longer visible.

It is likely that the addition of Driftstop to the tank mix increased the amount of wetting on fruit surfaces and therefore worsened the degree of fruit marking seen.

8.0 Acknowledgements

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Appendix 1: Plot Layout

Bold number is plot number, which is also treatment number

Hort16A Block

1	2	3	4	5	6	7	8	9										
									Buffer Row									
									10	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	
									1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
								Row	10	11	12	13	14	15	16	17	18	19

tank
fill

Hayward Block

Row																		
	1	**5**	**9**	**13**	**17**	Buffer Row												
	2	**6**	**10**	**14**	**18**													
	3	**7**	**11**	**15**														
	4	**8**	**12**	**16**														

Appendix 2: Hort16A Phytotoxicity Reference Scale

Appendix 3: Hayward Phytotoxicity Reference Scale