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Pesticide residues in hydroponic systems growing capsicum – an extended study

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Contents

1 Executive summary

The use of pesticides in nutrient solutions in hydroponic systems growing greenhouse vegetables is now a common practice in New Zealand. Advantages include:

- avoiding foliar spraying,
- minimising direct exposure of workers and produce to pesticide,
- reducing the direct impact of pesticides on beneficial insects in an IPM environment.

These systemic pesticides are generally incorporated in the nutrient solution in a run-to-waste (drench) or recirculation system. The fate of pesticides applied in this manner, the accumulation of residues in fruit, and the impact on the surrounding environment through run-off are not well understood or not reported. A review by Krishna and Carpenter (2000) identified that, particularly for New Zealand greenhouses, there was little information, on pesticide residues in hydroponically grown vegetables as a result of using pesticides in this way.

Vegfed's Fresh Sector (Cover Crops) commissioned a study during the 2002/03 growing season to assess the amount of residues in capsicum fruit as a result of drenching three pesticides into two types of growing media. An extended study during the 2003/04 growing season assessed three more pesticides, Topsin M-4A, Chess®, and Lannate®L used at 150 mL, 80 g and 100 mL per 1000 m^2 respectively, in three regional commercial trials covering the North and South Islands. In addition, we re-evaluated the use of Confidor®350 at 30 mL per 1000 m^2 by one other grower in Hamilton who uses rockwool as a growing medium.

This season's results indicated that:

- the type of growing medium and the nature of the pesticide used as a drench strongly influences the uptake and accumulation of the pesticide in the fruit;
- imidacloprid (Confidor) when drenched in a rockwool growing medium resulted in levels above the default 0.1 mg/kg for up to 3 weeks after drenching;
- levels of Topsin, Chess and Lannate, however, were found to be below the permitted maximum residue limits (MRL) in the three types of growing media assessed;
- pesticides assessed in this season's run-off followed a similar pattern to last season's. Levels, particularly in rockwool and pumice growing media, were generally highest just after fertigation was resumed following drenching, reducing to a minimum 7 days after drenching;

- an organic medium like sawdust may lock up the pesticides drenched into it, making them less available to the plant. Consequently, leaching into the surrounding environment is minimal. However, disposing of contaminated sawdust after use may be an environmental concern.

2 Introduction

The off-label use of pesticides in hydroponic systems in New Zealand is now a common practice in growing greenhouse vegetables. Pesticides are generally incorporated in the nutrient solution and recirculated or applied as run-to-waste to protect the crop from fungal diseases and insect pests such as whitefly, thrips, mites, aphids and caterpillars. The systemic pesticides used in this manner are generally recommended for foliar application and/or soil drenches. The advantages of this practice include:

- avoiding spraying pesticides on aerial parts of the crops,
- minimising the exposure of workers and produce to pesticides,
- reducing the effects of insecticides on beneficial insects, which is important for growers who use IPM.

The fate of pesticides applied in the nutrient solution or drenched in the various media used to grow vegetables is less understood or generally not reported. A review identified that there was little information on pesticide residues in vegetables crops grown hydroponically (Krishna & Carpenter 2000), particularly under New Zealand greenhouse management conditions. During the 2002/03 season, Vegfed's Fresh Sector (Cover Crops) commissioned a study of residues resulting from the drenching of three pesticides (metalaxyl, oxamyl and imidacloprid) in two growing media (sawdust and pumice). Results from these trials were reported in Krishna and Lill (2003). This study was further extended to this season to investigate the results of drenching three more pesticides – thiophanate-methyl, methomyl, pymethrozine and imidacloprid – in three combination types of growing media – rockwool/sawdust, rockwool/rockwool and rockwool/pumice.

3 Methods

Two commercial capsicum growers, one in the Christchurch region and one in the Auckland region, participated in this trial. After further discussion with the Fresh Sector (Cover Crops) committee, a Hamilton grower, who grows capsicum in rockwool, was included in the trial. For privacy reasons, the growers who participated in this trial are identified as Growers 1 (Christchurch), 2 (Hamilton) and 3 (Auckland).

3.1 Christchurch region

3.1.1 Grower 1

Grower 1 grows a variety of capsicum and eggplant for the domestic market. Twenty plants, five from each row, varieties 'Fiesta', 'Ferrari' and 'Special', were isolated for the trial. Previous trials showed that there were no varietal differences in the amount of pesticide residues found in the fruit. Untreated *Pinus radiata* sawdust was the growing medium on this property. Eight-week-old seedlings started in 'Grodan' rockwool blocks were transplanted directly into polythene bags containing sawdust on 22 July 2003. Nutrients to the plants were supplied through a drip feed to each plant.

The pesticides Topsin® M-4A (suspension concentrate), Chess® (wettable powder) and Lannate®L (water soluble concentrate) were first applied on 22 September 2003 when the plants were about 8 weeks old. Industry application rates are listed in Table 1. The industry standard of 2.5 plants/m^2 was used to calculate application rates for the trial. One hundred millilitres of a mixture of the three pesticides was applied to each bag using a syringe (See Appendix I for details of the application procedure). Plants were slightly water stressed prior to drenching by removing the drip feed to the bags during the regular fertigation cycle to allow for the rapid uptake of the applied pesticide. Fertigation to these plants was resumed in the following watering cycle.

Five plants, with four replicates, were drenched individually. Subsequent applications of Topsin were carried out every 4 weeks. The last application before sampling fruit for residues occurred on 17 November 2003. A total of three applications were carried out. The final application of Chess and Lannate took place on 21 November 2003 after seven applications at 10-day intervals. Following the final application of each pesticide, three mature green capsicum were randomly picked from each row (replicate) and fruit from rows 1 and 2 were combined. Also, fruit from rows 3 and 4 were combined to provide two samples for analysis on each sampling occasion. The fruit samples were weighed individually and recorded, and placed in a deep freeze in a labelled plastic bag within an hour of sampling. Further samples were taken 3, 7, 14, 21 and 28 days after the final applicatiocn of each pesticide (Information on sampling procedures is included in Appendix I).

Table 1: Application rates for different pesticides as used by cover crops growers were evaluated in three regional trials. After mixing, 100 mL of the mixture was applied to the root zone of each plant in a run-to-waste growing system.

Grower ID	Location	Growing media (starter block in medium)	Pesticide application rate (per 1000 m^2)			
			Topsin (mL)	Chess (g)	Lannate (mL)	Confidor (mL)
1	Christchurch	Rockwool/sawdust				
2	Hamilton	Rockwool/rockwool	150	80	100	30*
3	Auckland	Rockwool/pumice				

*Confidor was re-evaluated in the Hamilton regional trial because Grower 2 uses a rockwool starter/ rockwool slab. Confidor has been assessed in rockwool.

Run-off nutrient solution was randomly sampled from five plants on collection trays and then combined. A 50 mL sub-sample was drawn and syringed into a plastic container on days 1, 3, 5 and 7 after the first application of each pesticide and frozen. At the conclusion of the trial, all frozen samples were transported by TranzLink Refrigerated to Hill Laboratories, Hamilton, for residue analysis.

3.2 Hamilton region

3.2.1 Grower 2

Grower 2 is a commercial grower in a Hamilton suburb who grows capsicum for the domestic market. He grows capsicum in rockwool (Grodan Master Slabs) measuring 1000 mm (length) x 200 mm (width) x 75 mm (depth). About six-week-old plants started in 'Grodan' starter blocks were transplanted into rockwool slabs on 9 June 2003. Nutrients to each of the six plants were supplied individually by drip feed lines (Fig. 1). Four slabs, each growing six plants of the variety 'Spirit', were isolated for the trial. Each slab was considered a replicate. A total of 24 plants were isolated for the trial. The first drench with Topsin took place on 20 September 2003. About 100 mL of a pesticide mixture was applied per plant as a drench (Table 1). Two more drenches were applied at 4-weekly intervals, with the final application taking place on 15 November 2003. A total of three applications were carried out before sampling fruit for residue analysis.

Figure 1. Capsicum plants growing in a rockwool starter/rockwool medium.

The pesticides Chess and Lannate, and for this growing medium an additional pesticide Confidor (imidacloprid) not evaluated in rockwool before, were included in this season's trial. Confidor was included to ascertain

whether rockwool influences the amount of residues found in the fruit. The first application of these pesticides was carried out on 20 September 2003 followed by six more applications at 10-day intervals. The final application occurred on 19 November 2003. Drenching was done using a syringe to apply the pesticide directly into the rockwool starter block. A total of seven applications were carried out during the course of this trial. The plants were slightly water stressed prior to the drenching by removing the drip feed from each of the six plants per slab to allow for the rapid uptake of the pesticide after application. Fertigation to these plants was resumed in the following watering cycle.

After the last application of each pesticide, six mature green fruit were randomly picked from each slab (replicate). Fruit from slabs 1 and 2 were combined, and slabs 3 and 4 were also combined to provide two samples on each sampling occasion. The fruit samples were weighed individually and recorded, and placed in a deep freeze in a labelled plastic bag within an hour of sampling. Further samples were taken 3, 7, 14, 21 and 28 days after the final application of each pesticide (see Appendix I for details of procedure and sampling records).

Run-off nutrient solution, randomly sampled from five plants on collection trays, was combined and a 50 mL sub-sample was removed and syringed into a plastic container on days 1, 3, 5 and 7 after the first application of each pesticide and frozen. At the conclusion of the trial, all frozen samples were transported by TranzLink Refrigerated to Hill Laboratories, Hamilton, for residue analysis.

3.3 *Auckland region*

3.3.1 *Grower 3*

Grower 3 is a commercial grower located in the outskirts of Auckland who grows capsicum for the export and domestic market. He grows capsicum in pumice with two plants in each bag. About six-week-old plants started in 'Grodan' rockwool starter blocks were transplanted into pumice on 18 August 2003. Nutrients to each of the two plants per bag were supplied individually by drip feed lines (Fig. 2).

Five bags from each of four rows of the variety 'Special' were isolated for the trial. Each of the four rows was considered a replicate. A total of 40 plants were isolated and marked out for the trial. The first drench with Topsin took place on 22 September 2003. About 100 mL of a mixture was applied per plant (Table 1). Two more drenches were applied at 4-weekly intervals with the final application taking place on 17 November 2003. A total of three applications were carried out before sampling fruit for residues.

The first applications of Chess and Lannate were carried out on 22 September 2003 followed by six more applications at 10-day intervals. The final application took place on 21 November 2003. A total of seven applications were carried out during the course of this trial. Drenching was done using a syringe to apply pesticide directly into the rockwool starter block. The plants were slightly water stressed prior to drenching by removing

Figure 2. Capsicum growing in rockwool/pumice medium.

the drip feed from each of the six plants per slab to allow for the rapid uptake of the pesticide after application. Fertigation to these plants was resumed in the following watering cycle.

After the last application of each pesticide, six mature green fruit were randomly picked from each slab (replicate) and fruit from slabs 1 and 2 were combined into one sample. Fruit from slabs 3 and 4 were also combined to provide another sample on each sampling occasion. The sampled fruit were weighed individually and recorded, and placed in a deep freeze in a labelled plastic bag within an hour of sampling. Further samples were taken 3, 7, 14, 21 and 28 days after the final application of each pesticide.

Run-off nutrient solution randomly sampled from five bags on collection trays was combined, and a 50 mL sub-sample was removed and syringed into a plastic container on days 1, 3, 5 and 7 after the first application of pesticides and frozen. At the conclusion of the trial, all frozen samples were transported by TranzLink Refrigerated to Hill Laboratories, Hamilton, for residue analysis.

4 Results

A summary of pesticide residues found in capsicum fruit and in run-off for each grower is presented in Table 2 a, b, and c. A detailed laboratory report of the analysis is included in Appendix II.

4.1 Residues levels in capsicum fruit

4.1.1 Topsin fungicide

Topsin was applied as a drench at 4-weekly intervals for up to three applications to control fungal diseases. The systemic active ingredient thiophanate-methyl and its breakdown product carbendazim (active compound) did not appear to accumulate above the permitted default maximum residue limit (MRL) of 0.1 mg/kg in the fruit in any of the three media types assessed. The levels detected from the six samplings over the 4

weeks was estimated to be less than the limit of quantitation of 0.02 mg/kg for thiophanate-methyl and 0.01 mg/kg for carbendazim.

4.1.2 *Chess, Lannate and Confidor insecticides*

After seven applications at 10-day intervals of pymethrozine and methomyl in three growing medium types, pesticide residue levels detected in the fruit were less than the quantitation limits of 0.02 mg/kg. However, levels of imidacloprid varied between 0.08 and 0.13 mg/kg in the fruit when Confidor was applied as a drench in a rockwool/rockwool combination growing medium. Only in the sample taken 28 days after application was the level of imidacloprid below the default MRL of 0.1 mg/kg.

Table 2 a, b, and c. Summary of pesticide residues found in capsicum and in run-off nutrient solution under three media types and management conditions.

CHRISTCHURCH Grower 1: Growing medium - Grodan rockwool starter block in pine sawdust

	Thiophanate-methyl		Carbendazim		Pymethrozine		Methomyl	
*DALA	Capsicum fruit (mg/kg)	Run-off solution (mg/L)	Capsicum fruit (mg/kg)	Run-off solution (mg/L)	Capsicum fruit (mg/kg)	Run-off solution (mg/L)	Capsicum fruit (mg/kg)	Run-off solution (mg/L)
1	<0.02	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	0.04
3	<0.02	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	0.09
5	na	<0.01	<0.01	<0.01	na	<0.01	na	0.07
7	<0.02	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	0.06
14	<0.02	na	<0.01	<0.01	<0.02	na	<0.01	na
21	<0.02	na	<0.01	<0.01	<0.02	na	<0.01	na
28	<0.02	na	<0.01	<0.01	<0.02	na	<0.01	na

*DALA = capsicum fruit and run-off sampled after the last application of the pesticide

HAMILTON Grower 2: Growing medium - Grodan rockwool starter block in rockwool slab

	Thiophanate-methyl		Carbendazim		Pymethrozine		Methomyl		Imidacloprid	
DALA	Capsicum fruit (mg/kg)	Run-off solution (mg/L)	Capsicum fruit (mg/kg)	Run-off solution (mg/L)	Capsicum fruit (mg/kg)	Run-off solution (mg/L)	Capsicum fruit (mg/kg)	Run-off solution (mg/L)	Capsicum fruit (mg/kg)	Run-off solution (mg/L)
1	<0.02	5.00	<0.01	0.50	<0.02	3.50	0.03	4.00	0.11	2.30
3	<0.02	2.40	<0.01	0.46	<0.02	0.57	0.03	0.98	0.12	0.63
5	na	0.39	<0.01	0.26	<na	0.14	na	0.23	na	0.17
7	<0.02	0.23	<0.01	0.23	<0.02	0.09	<0.01	0.13	0.12	0.12
14	<0.02	na	<0.01	na	<0.02	na	<0.01	na	0.13	na
21	<0.02	na	<0.01	na	<0.02	na	<0.01	na	0.12	na
28	<0.02	Na	<0.01	na	<0.02	na	<0.01	na	0.08	na

AUCKLAND Grower 3: Growing medium - Grodan rockwool starter block in pumice

DALA	Thiophanate-methyl		Carbendazim		Pymethrozine		Methomyl	
	Capsicum fruit (mg/kg)	Run-off solution (mg/L)	Capsicum fruit (mg/kg)	Run-off solution (mg/L)	Capsicum fruit (mg/kg)	Run-off solution (mg/L)	Capsicum fruit (mg/kg)	Run-off solution (mg/L)
1	<0.02	0.25	<0.01	0.34	<0.02	0.96	<0.01	1.08
3	<0.02	0.31	<0.01	0.20	<0.02	0.40	<0.01	0.35
5	<na	0.17	na	0.24	na	0.68	na	0.12
7	<0.02	0.01	<0.01	0.05	<0.02	0.16	<0.01	0.01
14	<0.02	na	<0.01	na	<0.02	na	<0.01	na
21	<0.02	na	<0.01	na	<0.02	na	<0.01	na
28	<0.02	na	<0.01	na	<0.02	na	<0.01	na

4.2 *Pesticide residues in run-off*

Quantities of pesticides lost through run-off were found to follow a reducing trend over the 7 days depending on the pesticide and the growing medium to which it was applied as a drench (Table 2). In the rockwool/sawdust (Grower 1) combination, only traces of the fungicide thiophanate-methyl and its breakdown product carbendazim (<0.01 mg/L), and the insecticide pymethrozine (<0.01 mg/L) were found in the run-off in the first week after application. Methomyl levels varied slightly above the level of quantitation at between 0.04 and 0.09 mg per litre of nutrient solution.

However, when these same pesticides were drenched in a rockwool/rockwool growing medium (Grower 2), levels detected in the run-off nutrient solution were higher. Thiophanate-methyl and its breakdown product carbendazim (in brackets), pymethrozine, methomyl and imidacloprid varied between 5.00 and 0.23 (0.50 and 0.23), 3.5 and 0.09, 4.0 and 0.13, and 2.30 and 0.12 mg per litre of nutrient solution, respectively, after the first application of these pesticides.

In a rockwool/pumice growing medium (Grower 3), intermediate levels were detected. Thiophanate-methyl and its breakdown product carbendazim (in brackets), pymethrozine and methomyl varied between 0.25 and 0.01 (0.34 and 0.05), 0.96 and 0.16, and 1.08 and 0.01 mg per litre of nutrient solution, respectively.

5 *Discussion*

Residues detected in capsicum fruit for the additional four pesticides assessed during the 2003/04 growing season again indicate that the growing medium and pesticide (group) have a strong influence on the accumulation of residues when drenched around the root zone in a run-to-waste growing system. To keep this discussion in context it is important to remember that there is no national MRL set for the pesticides thiophanate-methyl and pymethrozine, and the default 0.1 mg/kg applies. For methomyl, the MRL set for solanaceous vegetables is 0.50 m/kg (NZ Food Standards 2002). Our previous findings (2002/03) are also discussed here.

When thiophanate methyl (Topsin), pymethrozine (Chess) and methomyl (Lannate) were applied as drenches in growing media including sawdust, rockwool and pumice at common industry rates, only traces of each residue were found in the fruit over the 4 weeks measured. In contrast, the accumulation and retention of imidacloprid residues did not show the expected decay over the same 4 weeks. Only in the fourth week from the last application was the level found to be below the default MRL of 0.1 mg/kg. It is well known that field capacity, 'Grodan' rockwool contains about 80% solution, 15% air pore space and 5% rockwool fibres. This superior retention of solution by rockwool slabs makes this pesticide more readily available to the crop, particularly when the plants are slightly stressed by the suspension of watering. Imidacloprid is also readily taken up by the plant and further distributed acropetally (moving up the plant). Good root-systemic action may

explain why imidacloprid residues were found at higher levels compared to those for sawdust and pumice. In last season's trial, imidacloprid residues found in capsicum grown in pumice were higher (mostly above the 0.10 mg/kg) than for capsicum grown in sawdust. In summary, the accumulation of imidacloprid in capsicum is pine sawdust < pumice < rockwool. The accumulation of thiophanate-methyl (precursor of carbendazim), pymethrozine and methomyl in capsicum may be related to the slower uptake of these pesticides compared to imidachloprid.

sawdust < rockwool < pumice

Pesticide residues found in run-off suggest that rockwool and pumice, both relatively inert substances, may readily release these pesticides when fertigation is resumed after drenching. In contrast, the lower levels detected in capsicum grown in sawdust suggest that an organic growing medium may lock up the pesticide, making it less available to the plant and preventing it from leaching out into the surrounding environment. The rate of leaching of these locked up pesticides may depend on the type of pesticide in question and run-off rate preferred by each grower under their growing conditions and management. In general, growers maintain a run-off rate of 20-30% or sometimes up to 50% to avoid salt build-up in the bags. An analysis of the growing medium for pesticide residues may reveal additional information that could be important for the efficient disposal of waste medium after several seasons.

6 Conclusion and recommendations

- Evaluations of six pesticides carried out over two seasons suggest that the nature of the pesticide (i.e. pesticide group) and media to which it is applied are important factors that influence the accumulation of pesticide residues in capsicum. The inclusion of an additional growing medium (rockwool slabs) demonstrated the importance of carrying out a pilot trial on a selected number of plants each time a grower intends to add a new pesticide to a run-to-waste system.
- An organic medium like sawdust appears to lock up pesticide and may make it less available to the plant. This may consequently reduce the amount leached to the surrounding environment. However, the disposal of pesticide-contaminated sawdust may be an issue for the environment. Efficacy may also be compromised and may need further investigation.
- Residue levels indicate that the use of imidacloprid (Confidor) or other similar pesticides in a run-to-waste system using rockwool or pumice as a growth medium should be discouraged.
- Leaching of pesticides to the surrounding growing environment is more of a concern in a rockwool and pumice run-to-waste growing systems. This is related to the rate of uptake of pesticide by the plant, the inertness of the medium in which the plant is grown, and percent run-off allowed in the subsequent fertigation following the drenching of the pesticide. For sawdust, however, there are no immediate concerns about the quantity of pesticides leached into the surrounding environment. There is, however, reason for concern about the disposal of the medium

after its useful life. The leaching rates for different pesticides drenched in different growing media may be important in assessing the impact of this pesticide application practice on sustainable vegetable production.

7 Acknowledgment

The commercial growers who participated are thanked for their support in carrying out these trials.

8 References

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