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Pesticide residues in hydroponic systems for growing capsicum

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1 Executive summary

The use of pesticides in nutrient solution in hydroponic systems for growing greenhouse vegetables is now a common practice in New Zealand. Advantages include the avoidance of foliar spraying, minimising the exposure to workers and produce to pesticides. These pesticides are generally incorporated in the nutrient solution and recirculated or run-to-waste. 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 less understood or not reported. A review by Krishna & Carpenter (2000) identified a lack of information, particularly under New Zealand greenhouse management conditions, on pesticide residues in hydroponically grown vegetables as a result of this use.

Vegfed's Fresh Vegetables Sector commissioned Crop & Food Research to determine residue profiles of three pesticides applied in run-to-waste management systems under industry practice. Fungicide metalaxyl-M (Apron® XL), and insecticides, imidacloprid (Confidor® 350) and oxamyl (Vydate® L) were investigated. Two commercial capsicum growers, one growing in sawdust in the SI, and another growing in a pumice/rockwool combination in the NI participated in the trial.

Apron, Confidor and Vydate were drenched at the rate of 55 ml (equivalent to 19 g metalaxyl), 36 ml (equivalent to 12.6 g imidacloprid) and 100 ml (equivalent to 24 g oxamyl) per 1000 m^2 respectively. Apron was applied at 4-weekly intervals, and Vydate and Confidor every 10 days. A total of three applications of Apron, and seven applications of Vydate and Confidor were made for the duration of the trial. Mature fruit were sampled at 1, 3, 7, 14, 21 and 28 days after the last application of each pesticide. The run-off nutrient solution was also sampled on 1, 3, 5 and 7 days after the first application of each pesticide.

Using Apron as a drench in sawdust did not result in any significant accumulation of metalaxyl in the fruit above the permitted MRL of 0.2 mg/kg. In contrast, residues of metalaxyl found in fruit when Apron was applied as a drench in rockwool/pumice were found to be close to the MRL, with one measurement above it.

For the insecticide Vydate, however, levels measured were consistently lower (traces) than the default 0.1 mg/kg for oxamyl. Growing medium may not have an influence on the accumulation of oxamyl in capsicum.

Imidacloprid residues found in fruit were all above the default level of 0.1 mg/kg when drenched at 10-day intervals in a rockwool/pumice growth medium. Levels in fruit ranged between 0.25 and 0.44 mg/kg. Drenching into

the rockwool starter blocks could have influenced the uptake of this pesticide. When applied in sawdust, however, levels were below the default MRL for imidacloprid.

Regular loss of pesticides into the surrounding environment through run-off in a drain-to-waste growing system is an important factor to consider in the sustainable production of vegetables. This loss appears to be exacerbated by the use of certain growth media. More losses to the surrounding environment occurred from a rockwool/pumice medium than from a sawdust medium.

In summary

- The growing medium may influence the accumulation of pesticides in capsicum. Drenching Apron at 4-weekly intervals, and Vydate and Confidor at 10-day intervals at industry rates in sawdust did not result in any significant residue levels in the fruit. When these pesticides were drenched at the same frequencies in a rockwool/pumice combination, residue levels found in the fruit were higher or tended to be closer to the MRL with the exception of Vydate. Imidacloprid residues were consistently higher than the permitted levels, whereas metalaxyl levels were just below the MRL. The drench medium did not appear to influence oxamyl accumulation in the fruit. When using rockwool/pumice as a growth medium, drenching with Confidor should be avoided as the 3-day pre-harvest interval (PHI) cannot be safely maintained. Care should be exercised in using Apron as a drench in capsicum as this pesticide accumulated at levels close to the MRL. All three pesticides included in this evaluation can be safely used as a drench in a sawdust medium growing capsicum.
- The type of growth medium used in growing capsicum may influence the amount of pesticide lost to the surrounding environment. The quantity of pesticides found in the run-off nutrient solution after the first application was consistently higher after drenching in rockwool/pumice compared to a sawdust medium. The use of appropriate growing media can minimise the negative impact of pesticides on the surrounding environment.
- Further research is needed to evaluate the safety of other pesticides used in capsicum and other greenhouse vegetables to assess their suitability for use in hydroponics. The retention of pesticides in various media growing different crops need further investigation of issues relating to sustainability.

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 mainly from root diseases and insect pests such as whitefly, thrips, mites, aphids and caterpillars. The systemic pesticides used in this manner are those that are generally recommended for foliar application and/or soil drenches. Advantages include avoiding spraying pesticides on aerial parts of the crop, minimizing the exposure of the produce and workers to pesticides. The fate of these pesticides, when applied in the nutrient solution or drenched in the different media used to grow vegetables is less understood or generally not reported. A review identified the lack of information on pesticide residues in vegetable crops grown hydroponically (Krishna & Carpenter 2000) particularly under New Zealand greenhouse management conditions.

Crop & Food Research was commissioned by Vegfed's Fresh Sector to measure fungicide (metalaxyl) and insecticides (oxamyl and imidacloprid) residues in capsicum fruit when these pesticides were applied as a drench in two growing media – sawdust and a rockwool/pumice combination (transplants in rockwool starter blocks) grown in the North and South Islands.

3 Methods

Two commercial capsicum growers, one in Christchurch and one in Auckland, participated in the trial.

3.1 Christchurch region

3.1.1 Harbour Head Growers

Chris and Liz Sinnott of Harbour Head Growers, have greenhouses on Main North Road, Waikuku. They grow a variety of capsicum and eggplant for the domestic market. Twenty plants, five from each row, varieties 'Special' (red) and 'Fiesta' (yellow) (Figure 1), were isolated for the trial. *Pinus radiata* sawdust was the growing medium on this property. Nutrients to the plants

Figure 1. Capsicum growing in sawdust at C&L Sinnott's property in Waikuku.

were supplied through a drip feed to each plant. Capsicum plants were transplanted on 17 June 2002 into a 3000 m^2 greenhouse. Transplants for the trial were started in a peat/bark medium by a commercial nursery.

The pesticides Apron, Vydate and Confidor were first applied on 1 September 2002 when the plants were about 11 weeks old. Plants were drenched using a measuring cylinder at an application rate of 55, 100 and 36 ml per 1000 m^2 respectively (See Appendix 1 for details of the application method). The industry standard of 2.5 plants/m^2 was used to calculate the application rates. The plants were slightly water stressed prior to application by removing the drip feed from the bags during the normal irrigation cycle to allow the rapid uptake of the pesticide applied. Irrigation was resumed about two hours later as part of the normal watering schedule.

A summary of the amount of each active ingredient expected to be delivered to the root zone by drenching each bag is given in Table 1. Five plants, replicated twice for each variety were drenched individually. Subsequent applications of Apron were carried out every 4 weeks. The last application, before sampling fruit for residues, occurred on 26 October 2002. A total of three applications were carried out. The final application for Vydate and Confidor took place on 21 October 2002 after six previous applications at 10-day intervals. Following the last application for each pesticide, five mature green capsicum were randomly picked from the two rows (replicates) and bulked into one sample for each variety. The sampled fruit were weighed and recorded individually, and frozen 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.

Table 1: Amount of each active ingredient supplied by drenching to the root zone of one plant, at each application in run-to-waste growing system.

Grower ID	Growing media	Metalaxyl-M (Apron) (mg/plant)	Oxamyl (Vydate) (mg/plant)	Imidacloprid (Confidor) (mg/plant)
HHG/CHCH	Sawdust	7.6	9.2	5.0
UG/AKLD	Rockwool /Pumice	7.6	9.2	5.0

Run-off nutrient solution was sampled from five plants on collection trays, bulked, and a 50 ml subsample was taken in plastic containers using a syringe on day 1, 3, 5 and 7 after the first application of each pesticide. At the end of the trial, all frozen samples were transported by TransLink Refrigerated to Hill Laboratories, Hamilton, for residue analysis.

3.2 Auckland region

3.2.1 Under Glass NZ

Commercial grower, Luke Marks, of Under Glass NZ, located in Drury Auckland, (Fig. 2) grows capsicum, cucumber and tomato for domestic and export markets. Luke grows his capsicum in pumice bags with two plants in each bag. Two-week old plants, started in rockwool starter blocks by a commercial nursery (Fig. 3), were transplanted on 6 September 2002.

Nutrients were supplied through drip feed into each bag. Four rows, eight plants per row, of the variety 'Special' were isolated for the trial. The first drench with Apron took place on the 21 September 2002. Further applications were made at 4-weekly intervals. A total of three applications were carried out before sampling fruit for residues began.

The first application of Vydate and Confidor were carried out on the 23 September 2002 followed by six further applications at 10-day intervals. The applications were made using a syringe 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 application by removing the drip feed from the bags in the trial plants to allow for the rapid uptake of the pesticide after application. Irrigation was resumed two hours later as part of the normal watering schedule.

After the last application of each pesticide, an average of five fruit were randomly picked from each row. Samples were bulked into one sample from two rows (replicates). Maturity of fruit at sampling varied between green and red. The sampled fruit were weighed and recorded individually, and frozen in labelled plastic bags within 1 h of sampling. Further samplings were carried out on day 3, 7, 14, 21 and 28 after the final application of the pesticides.

Figure 2. Capsicum growing in Under Glass, Karaka, Drury, Auckland.

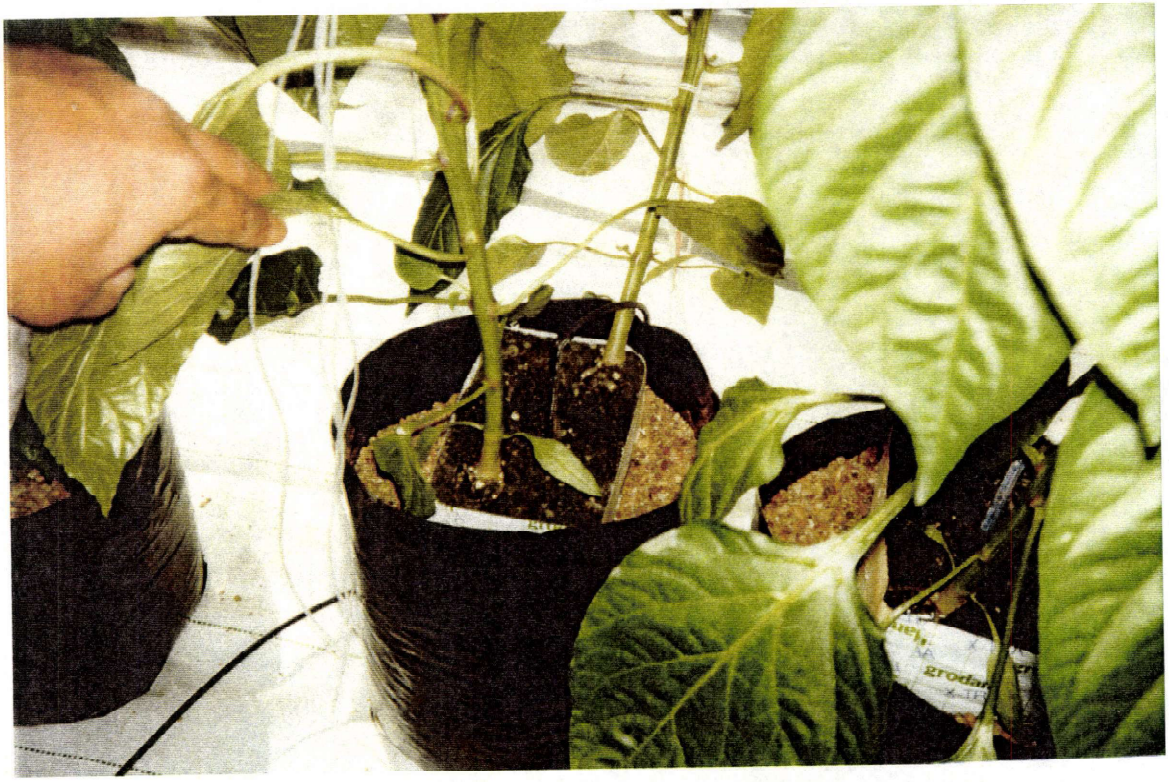

Figure 3. Capsicum transplants in rockwool starter blocks planted out in pumice bags. Note the two plants in each bag.

The run-off nutrient solution was sampled after the first application of the pesticides, from five plants placed on collection trays. The nutrient solution samples were bulked into one sample, and a 50 ml subsample was taken in plastic containers using a syringe on 1, 3, 5 and 7 days. At the end of the trial, all frozen samples were transported by TransLink Refrigerated to Hill Laboratories, Hamilton, for residue analysis.

4 Results

A summary of residues found in the fruit and run-off nutrient solution is presented in Table 2. A laboratory report of the fruit and nutrient solution analysis for pesticide residues is attached as Appendix 2. There was no varietal influence on the resultant pesticide residue in capsicum grown in sawdust and hence data were averaged over two replicates. Only one variety was used in the rockwool/pumice combination medium.

4.1 Residues in fruit

4.1.1 Fungicide Apron

The active ingredient metalaxyl in Apron, when applied at 4-weekly intervals for up to three applications for the control of common root diseases, did not appear to accumulate above the permitted maximum residue limit (MRL) in fruit when drenched in sawdust. Metalaxyl residues in fruit over the 4 weeks of the trial ranged between 0.06 and 0.02 mg/kg. In contrast, capsicum grown in rockwool starter blocks and transplanted in pumice showed higher accumulation of metalaxyl in the fruit. The range observed was between 0.15 and 0.24 mg/kg with metalaxyl residues being above or close to the permitted levels. The MRL (NZ Food Standards 2002) permits 0.20 mg/kg metalaxyl in fruiting vegetables.

4.1.2 Insecticides Vydate and Confidor

After seven applications at 10-day intervals, oxamyl residues changed very little over the sampling period and levels were well below the permitted MRL of 0.1 mg/kg (default, NZ Food Standards 2002) for capsicum grown in either sawdust or rockwool/pumice.

Higher levels of imidacloprid residue were found when capsicum was grown in rockwool/pumice. Imidacloprid levels were consistently higher than the default MRL of 0.1 mg/kg over the sampling period, which ranged between 0.25 and 0.44 mg/kg. In contrast, residues were well below the default MRL in capsicum grown in sawdust.

Table 2. Summary of pesticide residues found in capsicum under two growing media and management conditions.

Grower: Harbour Head Growers. Growth medium: sawdust

	Metalaxyl		Average	Run-off	Oxamyl		Average	Run-off	Imidacloprid		Average	Run-off
DALA[1]	1	2	(1+2)		1	2	(1+2)		1	2	(1+2)	
1	0.06	0.06	0.06	0.09	0.01	0.01	0.01	0.26	0.02	0.04	0.03	0.01
3	0.04	0.07	0.06	0.21	0.01	0.01	0.01	0.47	0.02	0.04	0.03	0.01
5	NA	NA	NA	0.21	NA	NA	NA	0.21	NA	NA	NA	0.03
7	0.04	0.06	0.05	0.17	0.01	0.01	0.01	0.14	0.03	0.03	0.03	0.05
14	0.01	0.03	0.02		0.01	0.01	0.01		0.02	0.03	0.03	
21	0.02	0.02	0.02		0.01	0.01	0.01		0.02	0.03	0.03	
28	0.02	0.01	0.02		0.01	0.01	0.01		0.02	0.02	0.02	

Grower: Under Glass. Growth medium: Rockwool/pumice

	Metalaxyl		Average	Run-off	Oxamyl		Average	Run-off	Imidacloprid		Average	Run-off
DALA	1	2	(1+2)		1	2	(1+2)		1	2	(1+2)	(1+2)
1	0.15	0.14	0.15	0.54	0.01	0.01	0.01	1.34	0.21	0.20	0.41	0.51
3	0.15	0.17	0.16	0.44	0.04	0.01	0.01	1.74	0.29	0.21	0.25	0.53
5	NA	NA	NA	0.18	NA	NA	NA	0.55	NA	NA	NA	0.23
7	0.15	0.15	0.15	0.12	0.02	0.02	0.02	0.24	0.30	0.34	0.31	0.15
14	0.29	0.10	0.20		0.01	0.01	0.01		0.34	0.31	0.33	
21	0.15	0.17	0.16		0.01	0.01	0.01		0.42	0.37	0.40	
28	0.29	0.19	0.24		0.01	0.01	0.01		0.43	0.44	0.44	

[1]Days after the last application of pesticide.
NZ Food Standards 2002 list the following permitted MRL in fruiting vegetable. Metalaxyl =0.2 mg/kg, Oxamyl=0.1 mg/kg (default), Imidacloprid=0.1 mg/kg (default).

4.2 Nutrient run-off

Quantity of pesticides lost through run-off were found to be variable depending on the pesticide concerned and the growing media. When Apron, Vydate and Confidor were drenched into sawdust, losses tended to be lower than that found in a rockwool/pumice medium one week after the first application. In sawdust, metalaxyl, oxamyl and imidacloprid ranged between 0.09-0.21, 0.14-0.26, and 0.01-0.05 g/m^3, respectively, whereas in pumice/rockwool they ranged between 0.54-0.12, 1.34-0.24, and 0.51-0.15 g/m^3.

5 Discussion

There appears to be an influence of growth medium in the accumulation of the pesticides (used as a drench) evaluated in capsicum fruit. To keep this discussion in context, the NZ Food Standards 2002 lists 0.2 mg/kg as the permitted MRL for metalaxyl in solanaceous fruiting vegetables. Also, in the absence of national standards for oxamyl and imidacloprid the default 0.1 mg/kg MRL will be used as a benchmark.

When these pesticides are drenched at industry application rates, into rockwool starter blocks in pumice bags, the accumulation of metalaxyl (Apron) and imidacloprid (Confidor) in the fruit was found to be higher than when drenched in sawdust. The levels were close to the permitted MRL for the metalaxyl but above the permitted levels for imidacloprid residues. In contrast, oxamyl (Vydate) residues found in capsicum grown in either media were consistently lower than the default MRL. These results suggest that there may be an interaction between the pesticide and growing medium on the accumulation of the pesticides in the fruit. This is more pronounced in imidacloprid when applied at the current industry usage rate. This effect is exacerbated when drenched in a rockwool/pumice growth medium.

The lower residue levels measured in fruit, particularly for the pesticides metalaxyl and imidacloprid drenched in sawdust, are surprising given the higher retention of these pesticide in sawdust growing medium. This may be due to the possible lock-up of these pesticide by sawdust. Alternatively, a rapid breakdown have occurred and hence less pesticide was available to the plant and finally to the fruit. When drenched in a rockwool/pumice growth medium, retention of pesticides was comparatively lower, but the growth medium may not be interfering with the uptake of these pesticides. The quantity of pesticides in the two media was, however, not measured at the end of the trial to confirm this.

The quantity of pesticides lost from the growth medium into the surrounding environment is an important issue for sustainable vegetable production. Our results suggest that pesticide loss into the surrounding environment was influenced by the type of growth medium used. Drenching pesticides in a rockwool/pumice medium contributed to greater loss compared to sawdust.

6 Conclusion

- When Apron (metalaxyl) and Confidor (imidacloprid) were drenched in sawdust at industry application rates, pesticide residues in fruit were found to be lower than the permitted MRLs. These pesticides can be safely used as a drench in sawdust used for growing capsicum;
- Drenching Confidor and Apron into a rockwool/pumice growth medium leads to levels above (imidacloprid) or close (metalaxyl) to the permitted MRL. Drenching Confidor into rockwool/pumice at the rate tested should be avoided if the minimum 3-day pre-harvest interval (PHI) is to be observed. Apron could be used but with caution;
- The type of growth medium did not affect the accumulation of oxamyl in the fruit. Vydate can be safely used at the rate used in capsicum grown either in sawdust or rockwool/pumice;
- The capacity to retain pesticides in the growth medium depended on the type of growth media used. Sawdust retained more pesticide than rockwool/pumice. In other words, loss of pesticide through run-off to the surrounding environment was greater from rockwool/pumice than from a sawdust growth medium;
- Further research is needed to assess the safety of other pesticides used in hydroponic systems growing capsicum. Direct measurements of the quantity of pesticides retained in the growth media in a run-to-waste system should be included in future trial work.

7 References

New Zealand Food Safety Authority. New Zealand (Maximum Residue Limits of Agricultural Compounds) Food Standards 2002.

Krishna, H; Carpenter, A. 2000. Pesticide residues in hydroponic systems growing tomato. Crop & Food Research Confidential Report No. 374, 29 pp.

8 Acknowledgement

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