FINAL REPORT

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Project Title:	Evaluation of pesticide persistence in hydroponic lettuce
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Research Provider:	NSW Department of Primary Industries (includes the former NSW Department of Agriculture)

HAL Project Number: VG02017

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Purpose of report:
This report presents the findings of a scoping study undertaken to evaluate the potential persistence of pesticides in hydroponic lettuce. It reports the results of research trials, describes the communication strategy and activities used to keep industry informed of the issue being investigated and identifies key recommendations of future actions for the industry.

Acknowledgement of funding sources:
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Media Summary

NSW Department of Primary Industries horticulturists, Mr Jeremy Badgery-Parker and Dr Sophie Parks have delivered a new benchmark for understanding and better managing the use of pesticides in hydroponic lettuce production.

Confidence in the safety and quality of fresh vegetables plays a substantial part in the growth and success of the fresh produce industry in Australia. Growers take this issue very seriously.

Jointly funded by the vegetable industry, through Horticulture Australia and NSW Department of Primary Industries, the recently completed project involved a two year scoping study to evaluate the potential persistence of certain pesticides in hydroponic lettuce and to develop better information for growers about the safety and quality of their produce.

"The hydroponic lettuce industry is a clean and efficient industry, growing high quality produce for Australian consumers. There is a wide range of practices and systems used in the industry and to ensure that growers can continue to improve the way in which they operate, we need to understand what is happening and what problems might exist." Mr Badgery-Parker said.

The hydroponic lettuce industry continues to work towards the adoption of good agricultural practices in all areas of production and this includes the integration of pest and disease management (IPM) strategies to minimise the impact and even eliminate the need for agricultural chemicals.

"Professional growers want to be sure that if they have to use a chemical to control pests or diseases, that the products they use will not affect the safety or quality of their produce." Mr Badgery-Parker said.

"We conducted research trials to get a better understanding of the potential for certain pesticides to remain in produce or the hydroponic system following their application. The project was set up to look at the potential risks so that better management practices and strategies can be developed for the industry." Dr Sophie Parks explained.

During the course of the project, 'field' trials were conducted to provide a controlled insight into existing industry practices and the potential for residues to persist following the use of pesticide under normal practices. In conjunction with this, growers around Australia were asked about their practices, including pest and disease management and an on-farm review was made of several properties.

"The information that we have been able to collect in this project provides a benchmark for what is happening in the industry with respect to pesticide use. By using this information, growers and researchers can find ways to continuously improve how farms are managed." Mr Badgery-Parker said.

"While our scoping trials have found that some pesticides could persist in leafy lettuce crops, some growers are setting an example for the industry by using very little and in some situations, no pesticides for pest management" said Dr Parks.

Mr Badgery-Parker added that "Several seminars and workshops, published articles and farm visits undertaken during the project have focussed on raising industry awareness about the potential for pesticide residues. This communication part of the project is about encouraging hydroponic lettuce growers to keep looking for and using pest management strategies that don't rely on pesticides."

An extension publication will be available in late 2005 to provide information for growers. These are practical, industry focussed outputs of the project. *Avoiding residues in hydroponic lettuce* is part of the Spray sense series being published by NSW Department of Primary Industries which provides general information on the issue of pesticide residues and potential management strategies.

Mr Jeremy Badgery-Parker and Dr Sophie Parks are located at the National Centre for Greenhouse Horticulture, Research Road, Narara.

Mr Badgery-Parker BScAgr MBA is the extension horticulturist for greenhouse and hydroponic horticulture with NSW Department of Primary Industries. He provides an extension service on all aspects of greenhouse and hydroponic production and is involved in a variety of research and extension projects for the protected cropping industry.

Dr Sophie Parks is the research horticulturist for greenhouse horticulture with NSW Department of Primary Industries. She is involved in a wide range of research and development projects providing the scientific basis for good agricultural practice and IPM in greenhouse horticulture.

Technical Summary

Project VG02017, supported by the vegetable industry through Horticulture Australia, conducted basic ‘field’ trials as part of a 2 year scoping study looking at the persistence of pesticides in hydroponic lettuce.

Experiments were set up to investigate the persistence of a fungicide (procymidone) and insecticide (methomyl) in a typical outdoor hydroponic system for leafy lettuce production.

Lettuce was grown in raised NFT (nutrient film technique) channels with the nutrient solution recirculated. The hydroponic system and practices used were equivalent to standard industry practice.

Methomyl and procymidone sprayed onto young and mature leafy lettuce, growing in a hydroponic system, was shown to leak into the recirculated nutrient solution hours after spraying lettuce. Residues of both pesticides in lettuce tissue remained above maximum residue limits (MRL) for at least 8 days after spray applications in young and mature lettuce plants.

When pesticides were applied at different doses to the nutrient solution, pesticides persisted in the solution for the duration of the crop. Additionally, at the lowest levels of contamination (about 10-20 $u\text{g}L^{-1}$) the lettuce plants took up the pesticide from the contaminated solution. The pesticide level detected in these lettuce plants was approximately one tenth of the MRL.

A case study investigating lettuce from a commercial and experimental hydroponic system demonstrated that methomyl residues can occur, without contamination of nutrient solution, and well after the minimum withholding period.

Introduction

In Australia, many types of lettuce are produced. Iceberg or Crisphead types are generally soil-grown, and leafy lettuce types such as Butterhead, Cos, Oakleaf, Rocket, Coral and Mignonette are widely grown in recirculated hydroponic systems. The lettuce industry in Australia produces over 135,000 tonnes, worth $76.2 million in 2001/2002 (Anon, 2004).

Confidence in the safety and quality of lettuce plays a substantial part in the growth of this industry in Australia. In recent years, during routine tests conducted as part of quality assurance programs, some hydroponic lettuce growers have found levels of pesticide residues in their produce above the MRL. NSW DPI sought funding assistance from Horticulture Australia to undertake a two year scoping study to investigate this issue.

In the production of hydroponic lettuce there is the potential for pesticide contamination of the nutrient solution, and residues in plants, particularly if the system is closed. Hatzilazarou *et al.* (2004) have detected organochlorine and pyrethroid pesticides in hydroponic nutrient solution after spraying greenhouse gerberas. Uptake of pesticides through plant roots from solutions has also been demonstrated. For example the fungicide metalaxyl was taken up by lettuce from a hydroponic solution (Dunstan 1992). In other studies methomyl added to irrigation water was taken up by ornamental *Hoya* (Heungens and Buysse 1998) and uptake of procymidone into shoots from solution was demonstrated in cucumber (Hisada et al. 1976). However few studies of this nature exist and the authors are not aware of any publication that investigates the effect of the hydroponic production system on pesticide residues in lettuce.

Two major pest problems in lettuce production are the insect Heliothis (*Helicoverpa armigera*, *H. punctigera*) and the fungal disease Sclerotinia (*Sclerotinia minor* and *S. sclerotiorum*) (McDougal, 2002). Common control of Heliothis has been through the use of the pesticide methomyl and for Sclerotinia the fungicide procymidone. Australian maximum residue limits (MRL) for pesticide residues in lettuce were originally established using data from field production systems. The MRL for procymidone in lettuce is 2 parts per million (ppm) and for methomyl the MRL is 1 ppm (Anon, 2002). Label directions for the use of pesticides on lettuce in Australia do not differentiate between lettuce varieties or type of production system.

The aim of the experimental work in this project was to investigate the persistence of a fungicide (procymidone) and insecticide (methomyl) in a typical outdoor hydroponic system for leafy lettuce production. Lettuce grown in raised NFT (nutrient film technique) channels and the recirculated nutrient solution was monitored during the cultivation of the crop to assess the affect of the growing system on pesticide residues.

Materials and Methods

Experimentation

Hydroponic cultivation

Experiments 1 and 2 were conducted from July-September 2003 and the third July-August 2004. The experiments were conducted outdoors in a recirculated NFT hydroponic system. The hydroponic system consisted of 20 PVC channels (10 cm wide, 5 cm deep and 18 m long) secured onto a metal frame at a height of 1 m. Eighty seven lettuces were grown in each channel 20 cm apart. Each channel had an independent nutrient solution supply of two connected 300 litre drums with one containing a submersible pump. Solution was pumped into the channels at a rate of 3800 L $hour^{-1}$ and channels were inclined at an angle to allow solution to drain back into the tanks by gravity. Solution was not replaced for the duration of each experiment.

The nutrient solution, made according to the Huett lettuce formulation (Huett 1993), was as follows: (mgL^{-1}) 116 nitrogen (N), 201 potassium (K), 22 phosphorus (P), 70 calcium (Ca), 20 magnesium (Mg), 26 sulphur (S), 2.5 iron (Fe), 0.22 manganese (Mn), 0.15 zinc (Zn), 0.21 boron (B), 0.03 copper (Cu) and 0.01 molybdenum (Mo). The electrical conductivity of the solution was maintained at 1.6 dSm^{-1}.

For experiment 1 and 2 (July –September 2003) an average of 0.7 mm of precipitation fell on 16 days out of 52. The average daily minimum temperature was 5.5 ^{o}C and the average daily maximum temperature was 20.0 ^{o}C. For experiment 3 an average of 2.6 mm of precipitation fell on 20 days of the 58 day experiment. Average daily minimum temperature was 3.5 ^{o}C and the average daily maximum temperature was 19.1 ^{o}C.

Seedlings and pesticides application

Seedlings of green oak leafy lettuce (*Lactuca sativa* L. cv. 'Krizet') propagated by Withcott Seedlings Pty. Ltd. were planted into the hydroponic system on 7 July 2003 for experiment 1 and 2 and on June 17 2004 for experiment 3. Applications of pesticides in this study are outlined in Table 1.

Table 1: Applications of methomyl and procymidone to lettuce in this study

Experiment number	Date of application	Crop age (weeks)	Application type	Dose (mg of active L^{-1})	Total applications
1	28 July 03	3	Sprayed on lettuce	50	1
2	25 August & 2 September 03	7	Sprayed on lettuce	50	2
3	16 June 04	3	Added to solution	0.1-10	1

For experiments 1 and 2 procymidone (Sumitomo Chemical Australia Pty Ltd) and methomyl (Crop Care Australasia Pty Ltd) were each applied as a spray at the recommended label dose of 50 mg L^{-1} with a wetting agent at the dose of 0.1 ml L^{-1}. A pressurised recirculating sprayer, operating at 17 L min^{-1}, was used to apply pesticide to lettuce. Lettuce foliage was sprayed until the point of runoff, ensuring thorough wetting of plants as according to the label. Experiment 1: Nutrient solution and lettuce samples were taken immediately prior to pesticide application. After spraying lettuce solution samples were taken from 10 rows daily, for 8 days and lettuce samples were then taken from the inner 8 rows at days 1, 2, 3, 5, 8, 15 and 22. Experiment 2: Nutrient solution and lettuce samples were taken immediately prior to both pesticide applications. Solution samples were also taken from the 10 rows daily, for 15 days and lettuce samples were taken from the inner 8 rows at days 1, 2, 3, 5, 8, 9, 10, 12, 14, 15, 21, 22 and 29.

For the third experiment procymidone and methomyl were supplied through the nutrient solution at the doses 0, 100, 200, 5000 and 10000 *u*g L^{-1}. All 20 channels of the hydroponic system were utilised. The five treatments were applied using a completely randomised block design with four blocks. Nutrient solution samples were taken from the 20 rows daily, for days 1 to 10, then at approximately weekly intervals on days 16, 23, 30, 37, 44, 51, 58. Lettuce samples were taken from each plot for pesticide analysis on day 23. Lettuce dry weight was measured at day 23 and at day 58.

For all experiments each solution sample of 1 L was collected into a sterile glass bottle. Between 5 and 10 lettuce heads were randomly selected from a row and placed in plastic bags to make up a 1 kg sample. Solution and leaf samples were stored at 4^{o}C for approximately 1 hour in transit to the analytical laboratory.

Additional information for the study was gathered using 6 mature cos lettuce plants, produced commercially, transplanted into the experimental hydroponic system, in the control channels without added pesticides. Methomyl had been sprayed onto lettuce 14 days previously. Lettuce was analysed after three days for methomyl and procymidone residues.

Pesticide analysis

Procymidone and methomyl were extracted from leaves and nutrient solution, and analysed with gas chromatography using accredited methods (National Association of Testing Authorities Australia) at the Australian Government National Measurement Institute laboratories (Laboratory 198, Pymble, NSW, Australia). For the analysis of nutrient solution water was extracted using dichloromethane and filtered through sodium sulphate before concentrating. Extracts were exchanged into hexane before analysis by gas chromatography (HP6890 with twin ECD and NPD detectors). Lettuce tissue extracts were cleaned up using gel permeation chromatography and analysed by gas chromatography (HP6890 with twin ECD and NPD detectors). The methods were validated using a duplicate, spiked and blank sample per batch of 20 samples. Spike recovery was considered acceptable at 40 -150 %. The recovery of the extraction method ranged between 82-126% for methomyl and between 60-131% for procymidone.

Statistical analysis

For solution and tissue samples a mixed model analysis was used to model log pesticide level over time. This was estimated via REML (residual maximum likelihood) using the ASReml computer program (Gilmour et al 1998). For Experiment 1 and 2, 8 replicates of lettuce and 10 replicates of solution were sampled at each time. For experiment 2, 4 replicates of solution were sampled for each pesticide dose at each time. Pesticide residue levels in lettuce for Experiment 3 were predicted with mean separation (LSD, 5%).

Results

Summary of results: Experiments were designed to investigate the potential for pesticide contamination of the hydroponic system and of hydroponic lettuce. Three experiments were carried out using a typical closed hydroponic system and lettuce and nutrient solution were monitored for pesticide residues:

1) Pesticides were sprayed onto an immature lettuce crop
2) Pesticides were sprayed onto a mature lettuce crop
3) Lettuce was grown in recirculating nutrient solution contaminated with low levels of pesticides

The data clearly showed that when lettuce was sprayed with pesticides the MRL for procymidone (2ppm) and methomyl (1ppm) was exceeded in lettuce tissue for at least seven days after the withholding period, in both mature and immature plants. Additionally, the pesticides sprayed onto the lettuce leaked into the hydroponic channels contaminating the recirculating nutrient solution. Even at the lowest levels of contamination (about 10-20 *u*gL^{-1}) the lettuce plants took up the pesticide from the contaminated solution. The pesticide level detected in these lettuce plants was approximately one tenth of the MRL.

Detailed results

For both immature and mature lettuce sprayed with pesticides, residues were detected in lettuce tissue and nutrient solution. Residues in lettuce and nutrient solution for the immature crop are presented in Tables 2 & 3 and for the mature crop in Tables 4 & 5.

A mixed model analysis was used to model log pesticide level (Y) over time, using ASReml. The fitted model is, Log(Y) = mu + time + *row* + *spline(time)*, where italicised terms are fitted as random terms. Back-transformed means of predicted values of residues in nutrient solution and lettuce tissue are presented.

In immature lettuce the concentration of procymidone was above the MRL for 22 days and the concentration of methomyl was above the MRL for 8 (Table 2). The nutrient solution was monitored for 8 days and pesticide residues were detected in the solution over this period (Table 3).

Table 2. Pesticide residues in lettuce tissue after spraying immature lettuce on day 1

Time (Days)	Mean procymidone concentration (mg kg^{-1})	Mean methomyl concentration (mg kg^{-1})
1	134.8	39.5
2	136.3	30.3
3	133.8	22.5
5	143.2	11.5
8	90.8	3.7
15	14.7	0.3
22	8.2	0.1

Table 3. Pesticide residues in nutrient solution after spraying immature lettuce on day 1

Time (Days)	Mean procymidone concentration (u g L^{-1})	Mean methomyl concentration (u g L^{-1})
1	162.8	157.2
2	22.4	120.9
3	8.4	12.8
4	5.9	12.1
5	7.7	11.3
6	44.1	9.5
7	51.0	9.3
8	37.2	9.4

In mature lettuce the concentration of both pesticides was above the MRL up to day 8 when pesticides were reapplied (Table 4). After the second spray application procymidone remained above the MRL for a further 21 days, methomyl for a further 13 days. Pesticide residues were also detected in the nutrient solution at each day of sampling (Table 5).

Table 4. Pesticide residues in lettuce tissue after spraying mature lettuce on day 1 and day 8.

Time (Days)	Mean procymidone concentration (mg kg^{-1})	Mean methomyl concentration (mg kg^{-1})
1	62.4	38.7
2	64.3	25.1
3	66.4	14.8
5	71.4	5.0
8	81.1	7.8
Second spray application		
8.04*	81.2	8.0
9	83.7	13.5
10	84.9	17.1
12	82.0	12.5
14	75.1	7.4
15	71.1	5.3
21	40.5	1.3
22	34.5	0.8
29	6.9	0.0

*On day 8 samples were collected immediately after spraying (8.0) and 2 hours after the spray application (8.04).

Table 5: Pesticide residues in nutrient solution after spraying mature lettuce on day 1 and day 8

Time (Days)	Mean procymidone concentration (*u* g L^{-1})	Mean methomyl concentration (*u* g L^{-1})
1	11.3	146.4
2	12.0	168.0
3	10.0	158.5
4	6.4	116.2
5	3.4	74.9
6	1.9	50.9
7	2.1	32.8
8	8.3	32.7
Second spray application		
8.04*	8.7	33.2
9	19.6	51.6
10	19.8	61.3
11	15.8	47.5
12	13.0	34.5
13	11.3	20.1
14	10.4	19.5
15	11.4	42.9

*On day 8 samples were collected immediately after spraying (8.0) and 2 hours after the spray application (8.04).

Pesticides were added to the nutrient solution at different rates for the third experiment. For both procymidone and methomyl residues persisted in solution, for all treatments, for the duration of the experiment (Figures 1 & 2). Pesticide contamination of the control treatment solution also occurred (probably through solution sampling) with a concentration of up to 20 *u*g L^{-1} pesticide.

A mixed model analysis was used to model log pesticide level in nutrient solution (Y) over time. The full fitted model was, Log(Y) = mu +treat+lin(time)+treat.lin(time) + *rep* + *rep.lin(time)* +*row* +*row.lin(time)* + *spl(time)* + *treat.spl(time)*+ *row.spl(time)* + *fac(time*), where italicised terms are fitted as random terms. Spl(time) and row were omitted from the final model for methomyl as was rep.lin(time) for procymidone.

There is a significant linear trend over time (*p*=0.017) for procymidone in nutrient solution (Figure 1). The response patterns for treatments 200 and 300 *u*g L^{-1} are not significantly different and the response patterns for treatments 5000 and 10000 *u*g L^{-1} are not significantly different.

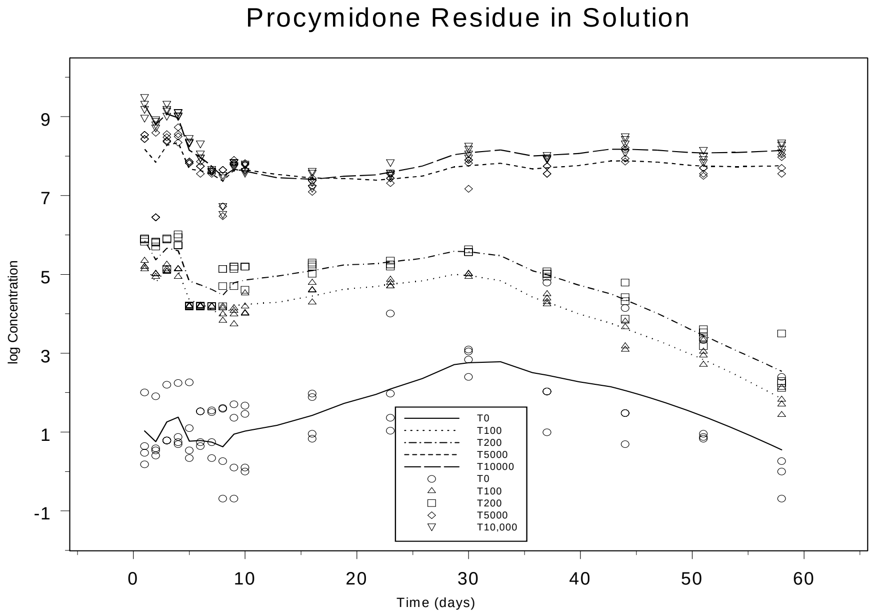

Figure 1. Log concentration of Procymidone (*u* g L^{-1}) in nutrient solution over time for Experiment 3 (log concentration 1 = 2.7 *u* g L^{-1}, log concentration 5 = 148 *u* g L^{-1}, log concentration 9 = 8103 *u* g L^{-1}, T0=0, T100=100, T200=200, T5000=5000 and T10000=10000 *u*g L^{-1})

There is a significant linear trend over time (p=0.003) for methomyl in nutrient solution (Figure 2). The response patterns for all treatments are different from the control (0 *u*g L^{-1}). The response patterns for treatments 100 and 200 *u*g L^{-1} are not significantly different. The response patterns for treatments 200 and 5000 *u*g L^{-1} are significantly different. The response patterns for treatments 5000 and 10000 *u*g L^{-1} are not significantly different.

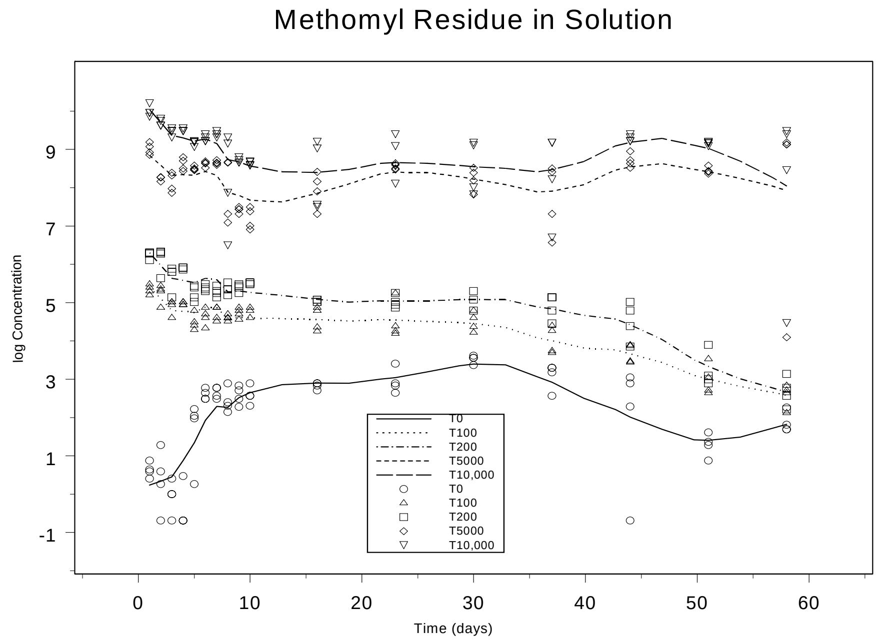

Figure 2. Log concentration of methomyl (*u* g L^{-1}) in nutrient solution over time for Experiment 3 (log concentration 1 = 2.7 *u* g L^{-1}, log concentration 5 = 148 *u* g L^{-1}, log concentration 9 = 8103 *u* g L^{-1}, T0=0, T100=100, T200=200, T5000=5000 and T10000=10000 *u*g L^{-1})

Lettuce growing in nutrient solution containing pesticides took up the pesticides into leaf tissue in all treatments (Table 6). Those plants growing in the control solutions also contained residues (possibly due to contamination from other treatments). Lettuce was analysed for pesticide residues 3 weeks after planting into the hydroponic system. Lettuce at this stage was immature and was not growth-limited by pesticides. However, there were clear differences in growth between treatments 58 days after planting into the hydroponic system. Concentrations of pesticides at 10000 and 5000 *u*g L^{-1} most severely affected growth.

Residue levels in lettuce tissue were modelled as Residue = mu + treat + *rep* where the italicised terms are fitted as random terms. Residue values were log(e) transformed and means back transformed for presentation in Table 6.

Table 6. Pesticide residues in lettuce tissue, and lettuce dry weights, after addition of pesticides to nutrient solution (values with the same letter are not significantly different)

Pesticide treatment (u g L^{-1}) *n* = 4	Mean procymidone concentration (mg kg^{-1}) *n* = 4	Mean methomyl concentration (mg kg^{-1}) *n* = 4	Dry weight at pesticide analysis (g) *n* = 4	Dry weight at final harvest (g) *n* = 4
10000	2.8a	50.2 a	0.357 b	1.921 b
5000	2.4a	21.3 b	0.369 b	2.027 b
200	1.4b	0.6 c	0.725 a	16.970 a
100	1.1b	0.3 c	0.664 ab	16.872 a
0	0.1c	0.1 d	0.616 ab	16.123 a
L.S.D	0.63	0.84	0.356	5.182

At the end of Experiment 3 six mature cos lettuces, obtained from a commercial grower, were placed into the control channels that contained low levels (not greater than 20 *u*g L^{-1}) of methomyl and procymidone in solution. The commercial lettuces had been sprayed 2 weeks previously with methomyl and had not been otherwise exposed to procymidone. These lettuces were analysed for pesticide residues 3 days after being in the experimental system. The results show (Table 8) that after 3 days the mature lettuce had taken up procymidone from the contaminated solution to approximately one tenth that of the MRL. The methomyl concentration in the lettuce was almost half the MRL, a result of the contaminated nutrient solution and/or previous sprays. This highlights the possibility that lettuce growing in commercial hydroponic systems are continually taking up these compounds to a concentration 1/10 that of the MRL.

Table 7. Pesticide residues in mature cos lettuce (mean of 6 replicates).

Residue mg kg^{-1}	Procymidone	Methomyl
Control	0.1	0.4

A Case Study – methomyl residues in lettuce from a commercial and experimental hydroponic system

As a result of the experimental work carried out in this project methomyl was included in the Cleanfresh pesticide monitoring programme based at the Sydney Markets, Flemington. In July 2005 lettuce obtained from a participating hydroponic grower in the Cleanfresh survey showed methomyl residues slightly above the MRL. This detection above the MRL occurred even though the grower used appropriate application techniques, including a withholding period of three days rather than the minimum of one day. Additionally, lettuce harvested from this farm receives a maximum total of only 2-3 methomyl sprays over the life of the crop.

Lettuce from the commercial farm was sampled a second time, again 3 days after the spray application. Methomyl residues were above the MRL of 1 mg kg^{-1} for all six lettuces as shown in Table 8. Methomyl was not detected in the nutrient solution immediately after spraying the crop. In addition to investigating commercial lettuce, mature lettuce growing in an experimental hydroponic system at the National Centre for Greenhouse Horticulture was also sprayed with methomyl. The lettuce had not been sprayed with any pesticide previously. The experimental lettuce was tested for methomyl residues after the minimum withholding period of one day and the results are presented in Table 9. The residues in the experimental lettuce one day after spraying greatly exceed the levels found in the commercial lettuce 3 days after spraying.

This case study has demonstrated that methomyl residues can occur in lettuce from two separate hydroponic systems, one being experimental, and the other of a commercial scale. The results also suggest that increasing the period between spraying and harvesting is likely to reduce the risk of residues above the MRL.

Table 8. Methomyl in commercial hydroponic lettuce (mature) 3 days after spray application

Lettuce type	Fresh weight (g)	Methomyl in lettuce (mg kg^{-1})
Green Cos	199.8	1.82
Green Cos	73.4	4.10
Green Cos	98.4	3.16
Red Cos	182.8	5.29
Red Cos	166.1	1.57
Red Cos	95.5	4.92

Table 9. Methomyl in experimental hydroponic lettuce (mature) 1 day after spray application

Lettuce type	Fresh weight (g)	Methomyl in lettuce (mg kg^{-1})
Green Oak	95.1	9.6
Green Oak	129.8	11.9
Green Oak	122.8	13.1
Green Oak	139.2	11.1
Green Oak	120.0	15.1
Green Coral	54.8	12.0
Green Coral	54.6	12.6
Green Coral	59.5	14.8
Green Coral	80.3	11.7
Green Coral	55.1	11.4

Technology transfer strategy and activities

The project aimed to assess the issue of pesticide residues in hydroponic lettuce through scoping trials investigating two key pesticides used in the industry. In conjunction with the scoping study, a base level communication program was conducted. This program aimed to (i) assess and if necessary raise awareness of the issue being investigated and (ii) to increase knowledge in the industry about key issues surrounding pesticides use. These two stages are prerequisites to behaviour change and adoption of new practices.

Review of industry practices

Questionnaire report

The questionnaire was designed as a short simple snapshot of some basic parameters pertinent to the project. It was intended to be as least onerous as possible. The questions sought basic information about a farm's production and pesticide use.

Production levels ranged from small growers producing a couple of hundred head of lettuce per week through to large growers turning off several thousand head per week. Most hydroponic growers are producing fancy lettuce types. A small proportion grow iceberg.

Management of nutrient concentration (electrical conductivity) is fairly consistent across farms. The most common set point for EC is 1.2 mS/cm with a range from 0.8 to 1.4 mS/cm. Seasonal adjustments are made around these set points. A small number of growers run a higher EC of 1.8 – 2.0 mS/cm. No information was collected on water quality. Nutrient pH is maintained around 6.0 to 6.5 with levels ranging from 5.5 to 7.0.

Replenishment of nutrient solution (dumping) varies considerably between farms. The most common strategy is to dump every 2 weeks, with the second most common strategy being to replace the nutrient solution every 8 weeks. Ten percent of farms do not dump at all. While most farms dump on a schedule basis, 20% do so for other reasons such as sodium levels, pH drift and plant appearance. The frequency of dumping may impact on potential uptake of pesticides from the nutrient solution.

With respect to pests and diseases, aphids are the most common pest encountered, followed by caterpillars. Thrips are the third most common pest. Pythium (or root pathogens generally) is the most problematic disease. Bacteria leaf spot and mildew are also key diseases. The next most prevalent disease reported is sclerotinia.

The majority of hydroponic lettuce is grown outdoor. Just under half of the growers who completed the questionnaire also produce some or all of their lettuce under netting or shadecloth. Two growers report that they grow under plastic (crop top) and 2 growers grow in greenhouses.

Within the group of 17 respondents a few use little or no pesticides. Use of chemicals appears to be related to farm location. Across all respondents, seventeen different active constituents are used for pest control and 13 different active constituents are used for disease control. Methomyl is the most commonly used insecticide, followed by spinosad, pirimicarb and permethrin. The most commonly used fungicides are iprodione and mancozeb & metalaxyl.

Active constituent	Example trade name	Pest
Insecticide		
Methomyl	Lannate	Cluster caterpillar, Heliothis and Western Flower Thrips
Spinosad	Success	Heliothis, Looper caterpillar and Western Flower Thrips
Pirimicarb	Pirimor	Aphids
Permethrin	Ambush	Cluster caterpillar
Fungicide		
Iprodione	Rovral	Sclerotinia
Mancozeb	Mancozeb	Downy mildew, Anthracnose, Septoria
& Metalaxyl	Ridomil Gold	Downy mildew, Anthracnose, Septoria

The questionnaire also sought to identify the most significant issues affecting hydroponic lettuce growers. The growing environment (weather) is considered to be the main production issue. Not surprisingly, weather is a bigger issue for outdoor producers. The second most common problems relate to marketing including prices and quality assurance. Rising production costs without an increase in returns is also a key issue for the industry. Management of pests and diseases, including the selection of pesticides is also a common problem.

Other issues encountered by some growers are dissatisfaction with available varieties, poor support provided by industry organisations and poor public perception in regards to hydroponics using ‘nutrients’ rather than ‘chemicals’.

Conclusions
The information collected in the questionnaire identifies a couple of key information areas that need to be addressed. The first relates to general hydroponic lettuce production practices. Practices vary and many growers are unsure of all elements of management that they need to be undertaking. The second knowledge area concerns pesticide selection and use. This also includes information on pest and disease identification. This area is potentially at the core of the issue surrounding pesticide residues.

Farm review
An on-farm review was conducted of 12 properties. This review looked at the farm set ups and production practices. A detailed examination was made of hydroponic systems, farm layouts and day to day management practices. This information will form a basis for an Agfact publication on hydroponic lettuce production which is expected to be available in early 2005. It has also been used in developing basic management strategies to minimise

chemical residue risks which are presented in an Agnote “Avoiding residues in hydroponic lettuce” which is currently being reviewed before publication.

Extension of information

Industry awareness

A five point communication strategy was used to address industry awareness of the project and the potential problem of persistent residues.

1. Conference presentation

A presentation entitled “*Are you giving consumers of hydroponic lettuce more than they asked for?*” was delivered at the Australian Hydroponic and Greenhouse Conference (AHGC) 2003. This conference is the premier event for the hydroponic industry. The conference was held in Melbourne in July 2003. The presentation provided background information on the issue, summarised the technical implications of pesticides in the root zone and gave an overview of the scoping study. The presentation was published in the conference proceedings.

Performance measure:

- 32 people attended conference presentation (approximately 25% of delegates)
- Presentation published in conference proceedings
  - Badgery-Parker, J and Parks, S (2003) “*Are you giving consumers of hydroponic lettuce more than they asked for?”*, Conference Proceedings, Australian Hydroponic and Greenhouse Conference, Melbourne 2003.
- Presentation published in industry magazine
  - Badgery-Parker, J and Parks, S (2003) “Are you giving consumers of hydroponic lettuce more than they asked for?”, *Practical Hydroponics and Greenhouses*, Issue 73, November/December 2003, Casper Publications.

2. Printed media

As noted above, the conference presentation was also picked up by the leading industry magazine – *Practical Hydroponics & Greenhouses* and was published in Issue 73, November/December 2003.

Brief summary articles were published in the national lettuce industry newsletter – *Lettuce Leaf* and in *Soilless*, the official member newsletter of the Australian Hydroponics and Greenhouse Association. These articles sought to make readers aware of the issue and of the scoping study project that was being conducted.

Performance measure:

- Information about the project and the issue was printed in 4 separate publications. These included conference proceedings, an international industry journal, lettuce industry newsletter and hydroponic industry newsletter.
  - Badgery-Parker, J and Parks, S (2003) “*Are you giving consumers of hydroponic lettuce more than they asked for?”*, Conference Proceedings, Australian Hydroponic and Greenhouse Conference, Melbourne 2003.
  - Badgery-Parker, J and Parks, S (2003) “Are you giving consumers of hydroponic lettuce more than they asked for?”, *Practical Hydroponics and Greenhouses*, Issue 73, November/December 2003, Casper Publications.
  - Badgery-Parker, J (2003) “Evaluating pesticide persistence in hydroponic lettuce”, *Lettuce Leaf*, Issue 9, April 2003, NSW Agriculture.
  - Badgery-Parker, J (2003) “Evaluating pesticide persistence in hydroponic lettuce”, *Soilless*, May 2003, AHGA.

3. Mail questionnaire

A direct mail questionnaire of hydroponic lettuce growers was conducted. This had two aims. Firstly, the mail out provided an opportunity to directly contact hydroponic lettuce growers around Australia and inform them of the project and the issue being investigated. The second aim of the questionnaire was to collect information about general industry practices and assess current awareness of the issue.

Performance measure:

- Mail survey posted to 198 addresses. The address list was a compilation of 3 databases from: (i) NSW DPI extension staff, (ii) a commercial industry stakeholder and (iii) the Vegetable Industry Development Officer.
- Of 198 surveys sent out 33 producers responded.
    - i. 24 surveys were returned (12%).
    - ii. 8 returns were received from people who have gone out of hydroponic lettuce production (4%).
    - iii. 2 returns were from people who were hydroponic vegetable growers but not lettuce (1%).

4. Direct communications

a) farm visits

During the course of the project, a site visit was made to 15 hydroponic lettuce farms. These were all in NSW, with the majority (10) being in Sydney, four located in the central Coast/Lower Hunter region and one on the mid north coast.
The farm visits provided opportunities to discuss the issue of pesticide residues specifically with growers, to gauge awareness and identify farm practices which may increase or reduce the risk of residues in fresh produce.

Performance measure:

- 15 hydroponic lettuce farms visited

b) farm review

A significant component of the farm visits was to collect information on practices and farm set ups which may impact on residues in produce. Twelve farms were reviewed in this context. The information collected has been combined with postal questionnaire returns and is being used in writing an Agfact on hydroponic lettuce production.

Performance measure:

- 12 hydroponic lettuce farms visited and practices were reviewed

5. Seminars

Three grower/industry seminars have been conducted which looked at key elements of this project from awareness of the issue through to discussion of potential management options. The project leader is the only extension horticulturist working with the greenhouse and hydroponic industries in Australia. As part of on-going extension activities, three seminars were conducted which drew attention to this project and the issue of persistent pesticide residues. These seminars were held in Coffs Harbour (11 Nov 2003) and Bundaberg (14 Nov 2003) and in Sydney (30 Apr 2004). The latter seminar was in conjunction with a managing root disease workshop for lettuce growers.

Performance measure:

- Project information and issue discussed at 3 seminars

Industry knowledge

The aim of developing industry knowledge centred on getting information on management strategies and farming practices to growers in a useable form. This involved gathering information about existing on-farm activities and farming set ups and providing appropriate materials to address knowledge gaps.

Performance measure:

- Publish an Agfact on hydroponic lettuce production

  The final draft is being prepared at the time of this report. Information collected in the postal questionnaire and on-farm reviews has been used to ensure that the publication addresses the identified knowledge gaps. It is expected that it will be published mid 2005. It will be direct mailed to hydroponic lettuce growers and will be available online and through the NSW DPI bookstore.
- Publish an Agnote on managing pesticide residues

  The final draft is being reviewed at the time of this report before a final edit and publication. It is expected that it will be published early 2005. The agnote will be direct mailed to hydroponic lettuce growers as well as being available online and through the NSW DPI bookstore.
- Provide information on pesticide use and selection

  To assist in developing industry knowledge on pesticide use and selection, a free copy of the Spray Sense book will be sent to hydroponic lettuce growers. Growers will also be informed of the Integrated Pest Management in Lettuce Information Guide and the associated field identification guide.
- Link with other related projects

  A telephone briefing was provided to a newly appointed pesticides project officer. This person is a core element of a new DPI project (CleanFresh) which is looking at residues in fresh produce and linking this information back to on-farm practices. The project officer was informed about this pesticide persistence project, its background, aims and results. Hydroponic lettuce will be one of the crops looked at in the CleanFresh project.

Evaluation and measurement of outcomes

Impact and adoption

Outputs achieved

A list of products currently registered that may need further investigation ☑

The scoping trials indicated that an important factor resulting in persistent residues in hydroponic lettuce could be the open leaf habit of fancy lettuce types. In this case, all products which are registered on lettuce, for which registrations are based on iceberg types, would potentially need to be assessed. The following products have been identified as being used by hydroponic lettuce growers:

Active constituent	**Example trade name**	**Pest**
Insecticide		
Methomyl	Lannate	Cluster caterpillar, Heliothis and Western Flower Thrips
Spinosad	Success	Heliothis, Looper caterpillar and Western Flower Thrips
Pirimicarb	Pirimor	Aphids
Permethrin	Ambush	Cluster caterpillar
Indoxacarb	Avatar	Bollworm, budwom
Alpha-cypermethrin	Fastac	Heliothis
Maldison	Maldison	Leafhopper, bugs, aphids, jassids, diamond backed moth, cabbage white butterfly and thrips
Dimethoate	Rogor	Leafhopper, bugs, aphids, jassids, leafminer flies, wingless grasshopper, thrips
Methidathion	Supracide	Western flower thrips
Chlorpyrifos		Western flower thrips
Acephate	Orthene	Western flower thrips
Bugmaster	Carbaryl	Heliothis, bugs, caterpillars
Lepidex	Trichlorfon	Bugs, caterpillars
Fungicide		
Iprodione	Rovral	Sclerotinia

Mancozeb & Metalaxyl	Mancozeb Ridomil Gold	Downy mildew, anthracnose, septoria Downy mildew, anthracnose, septoria
Dimethomorph	Acrobat	Septoria, anthracnose
Propineb & oxadixyl	Fruvit	Downy mildew
Prochloraz	Octave	Anthracnose
Metiram	Polyram	Downy mildew, septoria
Procymidone	Fortress	Sclerotinia
Thiram		Grey mould, anthacnose, septoria

A report of the degree of persistence of target pesticides in hydroponic lettuce ☑

The full experimental results are presented within this report in the sections materials and methods, results and discussion. A key recommendation of this project is to conduct further research and to initiate an industry meeting to facilitate and manage the response to these results.

An assessment of the need for specific pesticide labelling for protected cropping uses and potential for label changes ☑

A key recommendation of this project is that an industry working group be established to facilitate and manage the response to these results.

An agnote publication on pesticide persistence ☑

An agnote publication "Avoiding Residues in Hydroponic Lettuce" has been prepared as part of this project. This document has been produced to provide an immediate and on-going printed resource to assist in dissemination of information. It identifies the issue and sets out some management strategies which could be implemented to minimise risk of pesticides residues. The agnote is being reviewed prior to publication at time of this report.

Initiation of the development of a code of practice for hydroponics ☑

Ultimately, the development of a code of practice needs to be undertaken in conjunction with or by an industry working group. To initiate this process, this project has produced an extension publication identifying good agricultural practice (due mid 2005). Good agricultural practices provide a basis for the development of a code.

Assessment of Outcomes

The expected outcomes of this project are longer term than the 2 year scoping project itself and subsequently can not feasibly be assessed at this stage. However, some indicators are available and several extrapolations can be made.

Safer horticultural products and enhanced reputation for hydroponic produce

This is a long term outcome and is attributable to a large number of related and unrelated projects and events. This project has played an important role in awareness and dissemination of information which contributes to safer horticultural products. The project team is also involved in several other areas of work which will impact on this outcome.

The increasing adoption of quality assurance programs and implementation of pest and disease monitoring are precursors to the outcome of safer horticultural products.

Improved understanding of the relevance of pesticide recommendations to hydroponic lettuce cropping situations
This project was focussed on gathering basic scoping information to support or otherwise the anecdotal evidence that residues may persist even when registered products are used in accordance with the label. This has been achieved and is reported in the results section. Grower understanding of this issue has been addressed in conjunction with these scoping trials through several mechanisms – seminars, direct mail questionnaire, farm visits, telephone enquiries, conference presentation and proceedings, media and industry newsletter articles and preparation of two extension publications in addition to this project final report. Measurement of this outcome can not be achieved without a comprehensive industry assessment. This project did not include such a component.

Increased grower awareness of the importance of withholding periods
Formal assessment of this outcome can not be undertaken in the timeframe of this project. However, direct discussions with several of the growers whom were visited as part of the project revealed that many growers are now overly cautious about withholding periods. Some growers reported that they do not apply pesticides within 10-14 days of harvest to guard against residues. This is quite conservative compared to the required WHP for products used and indicates an awareness of the issue.

It is expected that this outcome will be further achieved by the dissemination of the 3 separate extension publications directly to growers.

A recent change by the APVMA, as part of its pesticide review program, to the use of procymidone will further highlight the importance of withholding periods and general use of pesticides to growers.

Increased grower awareness of chemical residues in horticultural crops
Formal assessment of this outcome can not be undertaken in the timeframe of this project. However, the mail out questionnaire was designed and undertaken to raise awareness of the issue. Two respondents who sought further information on selection and use of pesticides in hydroponic crops due to concerns about residues provide a small indication that general awareness has increased. This can not be fully evaluated without a comprehensive industry assessment which was not included as part of this project.

Greater interest in the use of IPM in intensive horticultural industries
Formal assessment of this outcome can not be undertaken in the timeframe of this project. Attributing behaviour change to specific projects is also difficult. There is, however, recognisable interest in IPM and better management options for pests and diseases as identified through enquiries received by the project leader during on-going extension programs. It is not possible to determine what contribution this project has made to date given that this industry has not undertaken any comprehensive benchmarking of its practices, attitudes or activities. However, a reasonable assessment of this outcome is expected to be made over the next five years due to linkages with a new project which is addressing on-farm

management of WFT and viral diseases. Our project team was involved in ensuring that hydroponic lettuce growers be one of the target groups for the IPM project.

Recognition by industry and stakeholders of the need for further evaluation of pesticide use in hydroponic systems
The project has been highly successful in raising awareness in the industry. This is further borne out by the invitation for Dr Sophie Parks to lead a workshop on the issue of chemical residues and hydroponics at the 3rd Australia Lettuce Industry Conference in May 2005 at Werribee, Victoria.

Lower incidence of MRL breaches in protected cropping situations
It is not possible to evaluate this expected outcome at this stage, however, the project identified that there were knowledge gaps in the industry with respect to what pesticides can be used and the application and selection of pesticides. To address these gaps, hydroponic lettuce growers are being provided with several extension publications including (i) an agnote which describes the issue of pesticide residues and some management strategies to address them, (ii) an Agfact which describes good agricultural practices in producing hydroponic lettuce and (iii) a book (Spray Sense) which is a compilation of plain English factsheets on pesticides including selection and use.

Discussion

Research

The experimental research highlights that pesticide residues in hydroponic lettuce is a genuine issue. However, being a scoping study, this project was limited and provides only a narrow base of information. For example, to reduce the cost of analyses two pesticides were generally used together as a treatment. Reliable pesticide decline data instead requires single pesticide treatments. Given the implications of these results for the lettuce industry further work is required to include a range of pesticides, lettuce varieties, seasonal effects, and production systems.

There are several issues important to highlight from this research. 1) pesticide residues can occur and persist for some time in hydroponic lettuce. The data clearly showed that when lettuce was sprayed with pesticides the MRL for procymidone (2ppm) and methomyl (1ppm) was exceeded in lettuce tissue for at least seven days after the withholding period, in both mature and immature plants. 2) pesticide contamination of nutrient solution can occur in hydroponic lettuce systems. The pesticides sprayed onto the lettuce leaked into the hydroponic channels contaminating the recirculating nutrient solution. Further highlighting this risk was the unexpected result of low range contamination in the nutrient solution of controls. 3) lettuce plants can take up pesticides from nutrient solution into shoots. Even at the lowest levels of contamination (about 10-20 $u\text{gL}^{-1}$) the lettuce plants took up the pesticide from the contaminated solution. The pesticide level detected in these lettuce plants was approximately one tenth of the MRL. A serious potential problem with this situation is the development of pest and disease resistance.

Extension

This project has played an important role in awareness and dissemination of information which contributes to safer horticultural products. Some key information areas that need to be addressed were highlighted by the questionnaire. The first relates to general hydroponic lettuce production practices. Practices vary and many growers are unsure of all elements of management that they need to be undertaking. The second knowledge area concerns pesticide selection and use. This also includes information on pest and disease identification. This area is potentially at the core of pesticide residue issues experienced in the hydroponic lettuce industry.

Directions for pesticide residue research in hydroponic and greenhouse crops – where to from here?

The project VG02017 has highlighted that pesticide residues in hydroponic lettuce are a serious issue. There is a strong need for a coordinated approach to be taken in the registration of pesticides for use in the greenhouse and hydroponic industry. Many issues need to be considered such as those concerning occupational health and safety as well as crop residues.

It is apparent that the complex issue of pesticide use in the greenhouse and hydroponic industry has not yet been adequately dealt with elsewhere. Data obtained from Europe by the APVMA reflects only the use of pesticides in covered crops grown in soil. Scientists in the US are currently organising a workshop for mid-2006 to consider the issue of pesticide use in hydroponics and greenhouses. The Australian industry has an opportunity to be part of this workshop.

The potential problem with hydroponics

In the production of hydroponic crops there is the potential for pesticide contamination of the nutrient solution, and for the accumulation of pesticides in plants, particularly if the system is closed. Previous research has indicated that this is possible. For example Hatzilazarou *et al.* (2004) detected organochlorine and pyrethroid pesticides in hydroponic nutrient solution after spraying greenhouse gerberas. Uptake of pesticides through plant roots from solutions has also been demonstrated. For example the fungicide metalaxyl was taken up by lettuce from a hydroponic solution (Dunstan 1992). The project VG02017 demonstrated that nutrient solution can become contaminated with procymidone and methomyl and also taken up by lettuce through roots. Low levels of residues in plants are particularly a problem as this situation encourages pest and disease resistance.

Considerations for R & D on pesticides in the greenhouse and hydroponic industry

- The range of crops and types of systems being grown in hydroponics and greenhouses
- Application methods that are appropriate for the system being used eg one that takes into account the volume of water being recirculated in a hydroponic system in addition to the area being sprayed.
- Issues beyond crop residues such as occupational health and safety
- The potential use of collected data such as that for quality assurance or monitoring (eg Clean Fresh survey – Sydney Markets)
- Participation in the US workshop mid-2006 on pesticide use in the greenhouse and hydroponic industry (coordinated by Prof. Charles Meister, University of Florida)
- The need for Good Laboratory Practice accredited researchers so that data can be used to establish MRLs

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Appendix

Appendix 1 Conference presentation

AUSTRALIAN HYDROPONICS & GREENHOUSE ASSOCIATION CONFERENCE 2003

ARE YOU GIVING CONSUMERS OF HYDROPONIC LETTUCE MORE THAN THEY ASKED FOR?

Jeremy Badgery-Parker MBA, BScAgr, Churchill Fellow 2001
Extension Horticulturist (protected cropping)

Introduction

Confidence in the safety and quality of fresh vegetables plays a substantial part in the growth and success of the fresh produce industry in Australia. This issue is taken very seriously by growers and consumers alike.

There are many advantages of hydroponic production systems, not least of which is the increased opportunity for growers to reduce pesticide use. The production of crops in hydroponic systems instead of the soil (and especially when combined with a good greenhouse structure) means that there are fewer opportunities for pests and diseases to attack the crop. In addition, maintaining a tightly controlled growing environment as is possible with a hydroponic system, often means that a healthier and faster growing plant results. These advantages reduce the need for pesticides. However, the need for chemical controls has not been fully done away with yet.

There are a number of training and research initiatives that aim to further improve the safety and efficacy of pesticide use in horticultural industries and with the adoption of quality assurance programs, the industry is becoming better equipped and more skilled than ever in this area. However, pesticide use in protected cropping systems continues to be an area that requires a better understanding. Most growers will agree that they still rely on pesticides at least at some point during the cropping cycle.

Besides chemical residues, however, there can also be natural compounds which potentially affect the safety and quality of fresh vegetables. Commercial limits on the nitrate content in leafy vegetables are enforced by the European Union (Anon 2001). The need for good practices in food production, in order to limit the amounts of nitrates in foods, is emphasized by the World Health Organisation (Anon 1995).

Background

Pesticide residues

Pesticide residue analyses, conducted on some commercial hydroponic vegetable enterprises have indicated that some pesticides may be more persistent in hydroponic production systems. Usually, pesticide recommendations are developed from treatments applied to field grown crops and do not consider protected cropping systems (both greenhouses and hydroponics) that can shorten growing periods and cropping cycles, and may lead to increased chemical uptake in crops such as lettuce.

In recirculating hydroponic production systems, there is a suggestion that systemic pesticides may enter the nutrient solution during application and be retained, leading to continual uptake by the crop after the initial application. This would lead to elevated levels of residues over extended periods and may result in maximum residue limits (MRLs) being exceeded even though use is in line with chemical label directions. This is potentially a problem in all hydroponically produced crops.

There are two important issues to consider.

1) The systemic activity of some pesticides is greater when they are applied to the root zone
2) Multiple applications of some pesticides can increase the level of residues.

<u>Increased systemic activity of pesticides</u>

Some pesticides are more systemic when applied to the root zone than when applied to the foliar part of the plant. However, application rates and residue data are based on the application of the product to the foliar part of the plant. In such a case, greater movement of the compound into the plant could occur if it gets to the root zone resulting in higher or more persistent residues.

The application of pesticides through the hydroponic nutrient solution has been researched as early as the 1970's. In a trial by Dunne and Donovan (1978) it was shown that a systemic pesticide (pirimicarb) could readily be taken into the plant from the nutrient solution. While this work was aimed at determining whether the method of application was effective, it demonstrates that the chemical has a bigger impact when applied to the roots. This illustrates the potential for excess application should a pesticide, registered for and applied to the foliar part of a plant, get into the root zone. Furthermore, the risk of root zone contamination will be greater if the product is applied to run-off levels.

Price (1975) also found that much lower concentrations of chemicals would be necessary for complete pest control when applied through the nutrient solution. This highlights the fact that the pesticides can more readily get into the plant through the roots. It also indicates that only a small amount of chemical is needed to cause the same effect. In trials with metalaxyl in hydroponic lettuce, Dunstan (1995) found that residues of were significant when this fungicide was applied via the nutrient solution.

<u>Recirculating systems</u>

The second issue involves recirculating systems. If a pesticide is in the nutrient solution which is then recirculated, it could be continuously reapplied to the crop for an extended period after the initial application. In this case, greater movement of the compound into the plant could occur resulting in higher or more persistent residues.
At the very least, it would mean that the withholding period might not be correctly observed.

Sances et al (1993) demonstrated that multiple applications of methomyl, at short intervals, in field grown head lettuce significantly increased residues. A similar effect could be expected in a hydroponic system if the chemical is present in the nutrient solution. Aplada-Sarlis et al (1994) and Garcia et al (1997) found from trials in hydroponic tomato crops that procymidone and methomyl, respectively, are more persistent than the required withholding period would suggest. Aplada-Sarlis et al (1994) suggest that the high residues following successive applications of procymidone may be a result of there being no dilution effect as the crop was already mature and that the greenhouse environment protected the chemical from wind, rain and ultra violet radiation.

If there is potential for pesticides to be more readily taken up from the root zone and also potential for pesticides to be recirculated in hydroponics, what does that mean for hydroponic growers? In particular, what does it mean for growers using recirculated systems such as the hydroponic lettuce industry?

On the other hand, work in the United Kingdom (O'Neill 1998), reported in the ADAS Research Review 1997/98, indicated that the systemic fungicides carbendazim and propamocarb when applied to hydroponic tomatoes and cucumbers did not show an increased the risk of higher residues when used through recirculating systems compared with flow-through systems. And following trials in France in 1977-78, as part of the evaluation of procymidone by the Food and Agriculture Organisation of the United Nations (FAO) and World Health Organisation (WHO), it was suggested that the more rapid plant growth in greenhouse lettuce was a major part in the dilution of residues (Anon 1981).

So, are pesticide residues an issue?

During routine residue tests as part of quality assurance programs, some hydroponic lettuce growers recently turned up residues in their produce which exceeded the maximum residue limits. Did these growers make a mistake when applying the pesticide or is the above speculation more real than we would hope?

In May 2001, a routine residue test conducted within a quality assurance program, showed a procymidone level of 1.96mg/kg against the MRL of 2 mg/kg. This is not a problem in itself, but the grower's records indicated that this chemical had not been applied for 21 days prior to harvesting the test sample. A repeat test (in June 2001) using a new sample that had been sprayed with procymidone eight days previously, showed a level of 6.75mg/kg. This was over three times the MRL, yet the product has only a two day withholding period.

No obvious problem in the application of the chemical was found. More investigation was needed so a research project was initiated to look at the problem. Since the project proposal was submitted, further incidents have been reported. For example, in June 2002, another hydroponic lettuce grower found, through their in-house quality assurance testing program, residues of procymidone up to 6 times the MRL four days after application. Analyses conducted four weeks after application continued to show residues above the MRL of 2 mg/kg.

This information is from the recently published report Monitoring Pesticide and Cadmium Residues in fresh fruit & vegetables 1987-2001. For hydroponic lettuce there have been 56 samples tested with six samples over the MRL compared to field grown lettuce with 361 samples, and only nine over the MRL. That is, almost 11% of samples of hydroponic produce showed a problem, compared to just 2.5% for soil grown lettuce.

Nitrates

Consumer products high in nitrates are considered potentially hazardous to human health. For example, a high dietary intake of vegetables high in nitrate is associated with gastric cancer (Kim et al. 2002). High nitrate levels occur in leafy vegetables in Europe, and this is particularly associated with low light levels in winter. Light levels in Australia are not necessarily limiting, nonetheless, there is little information regarding the levels of nitrate in Australian produced vegetables, and this may affect long term access to export markets.

One issue highlighted by a Queensland study (Lyons et al. 1994) is the possibility that hydroponic lettuce has greater nitrate levels than field grown lettuce. Australia is the largest hydroponic lettuce producer in the world and this crop dominates the hydroponics industry in NSW, which is concentrated in the Sydney Basin and Central Coast areas.

Current projects

Evaluation of pesticide persistence in hydroponic lettuce

This project is investigating the issue of potential pesticide residues in hydroponic lettuce. Over two years, a series of lettuce crops will be grown. The application of key pesticides will be monitored, residues tested in the crop and in the nutrient solution and the process analysed in order to evaluate the persistence of chemicals in crops being grown in recirculated systems.

The project involves testing normal industry practices in relation to these pesticides and establishing the existence and cause of the problem. This will then enable solutions or management strategies to be developed to ensure the integrity of the industry is maintained.

The two commonly used chemicals which are being looked at in the first instance are procymidone and methomyl.

Procymidone (Sumisclex, Fortress, Campbell Cyon) is a dicarboximide fungicide. It is a fairly selective, moderately systemic group B fungicide. Procymidone is currently registered for the control of *Sclerotinia* rot in lettuce. A thorough wetting of the plants is important so the product is applied to the leaves to the point of run-off. The product has a two day withholding period. Procymidone is a fairly stable compound except in alkaline media. It has a locally systemic action when applied to the aerial parts of the plants, but shows a marked increase in systemic effect following application to the roots.

A key point to note is that the moderate systemic activity of this chemical is increased when it is applied to the root zone and results in movement of the chemical from the roots to the leaves and flowers (Anon 1981).

The second product, Methomyl (Lannate, Electra, Marlin, Nudrin), is a carbamate systemic insecticide belonging to group 1A. It is a broad spectrum insecticide that is toxic to insects by both contact and ingestion. This product is currently registered for the control of budworm (*Heliothis*) and cluster caterpillar in lettuce. Methomyl is commonly used in the hydroponic lettuce industry. The product is applied to achieve a thorough, uniform coverage and has a one day withholding period. Methomyl only decomposes slowly when it is in a closed system, in an aqueous solution. Aeration, sunlight, alkalinity and high temperatures can increase the rate of decomposition.

These two chemicals are being used for this project because they have some systemic activity, are currently registered for lettuce and are commonly used by the industry, and in the case of procymidone, a problem has been demonstrated.

Nitrate in hydroponic lettuce in the Sydney Basin ***(Dr Sophie Parks)***

This pilot study aimed to quantify nitrate levels in hydroponically produced lettuce, from the Sydney Basin, over a period of six months. This work was supported by a NSW Agriculture grant.

Results and discussion

Recommended European limits on the nitrate concentration of fresh lettuce are 0.35% in summer and 0.45% in winter. Nitrate levels in fresh lettuce obtained for the Sydney Basin were collected from eight producers, on four occasions, between December 2002 and June 2003. Mean nitrate levels in lettuce, over time, were well below the recommended European limits, ranging from 0.097 – 0.144%. Nitrate levels were not significantly affected by season. Most variation occurred in the range of nitrate levels obtained for lettuce from different producers. This indicates that the greatest affect on nitrate levels in lettuce, in Australia, are grower practices. Further work is proposed to carry out a more extensive survey that includes a range of vegetables, and to identify grower practices that minimise nitrate levels. Quantification of nitrate levels in Australian produce will ensure long term access for growers to export markets.

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Appendix 2 Spray sense publication to be made available on NSW Department of Primary Industries website

DRAFT ONLY

Minimising pesticide residues in hydroponic crops

Confidence in the safety and quality of hydroponic crops plays an important part in the growth and success of the industry. There are many advantages in using hydroponic production systems, including an increased opportunity for reduced pesticide use. Hydroponic systems are soil less systems which maintain a tightly controlled growing environment allowing fewer opportunities for pests and diseases to attack the crop.

The potential for pesticide residues in hydroponic crops

Pesticide recommendations are usually developed using field grown crops. These recommendations do not allow for differences in protected cropping systems (both greenhouses and hydroponics). These differences include shorter growing periods and cropping cycles and the use of different varieties. These aspects may lead to increased chemical uptake and higher residue levels in some crops. One example is lettuce, particularly the open leafed varieties typically grown in hydroponic systems.

In recirculating hydroponic production systems, there is a risk of systemic pesticides entering the nutrient solution during application and being retained. This can result in continued uptake of the pesticide by the crop, long after the initial application. Contamination of the nutrient solution is more likely when plants are small and do not completely cover the planting hole. The presence of pesticides in the nutrient solution can lead to elevated levels of residues over extended periods and may result in the maximum residue limit (MRL) being exceeded, even though application was in accordance with label directions. This situation may also result in pest and disease resistance to the pesticide, reducing its effectiveness.

Research by Parks and Badgery-Parker (2005) has demonstrated that pesticide residues in hydroponic lettuce are a real issue. They investigated methomyl residues in commercial and experimental hydroponic lettuce systems. The pesticide was sprayed according to label directions on mature lettuce. In the experimental system the MRL was well exceeded for methomyl in lettuce at the recommended withholding period of one day. In the commercial system the MRL for methomyl in lettuce was still exceeded three days after spraying. Additionally, low levels of methomyl were found in the nutrient solution of both systems.

- **Increased systemic activity of pesticides**

Many pesticides can move quickly through the plant when they are applied to the root zone rather than the foliage. Application rates and residue data are normally based on application of the product to the foliage. Research has shown that hydroponic systems increase the likelihood of delivering pesticides to the root zone. The concern is that as a result, higher or more persistent residues may occur.

High levels of pesticide residues can occur in hydroponic crops when delivered through the nutrient solution. For example high residues of the fungicide metalaxyl were found in lettuce when the fungicide was supplied exclusively through the hydroponic solution (Dunstan, 1995). This study shows that pesticides can move readily through plant roots. It also highlights the potential for increased pesticide application when products registered for foliar application get into the root zone.

Persistence of low levels of pesticide in hydroponic solutions has the potential to induce pest and disease resistance to pesticides. Dunne and Donovan (1978) showed that a systemic pesticide (pirimicarb) could readily be taken into the plant from the nutrient solution and was effective in pest control at low levels in the plant. Although this may appear to be an effective way of reducing pesticide use, exposing a pest population to a low dose of chemical, for a lengthy period, can rapidly induce pest resistance to the chemical.

- **Effects of recirculating systems and the growing environment**

Hydroponic systems have the ability to deliver pesticides to plant roots over long periods, particularly if the nutrient solution is recirculated. Such systems include nutrient film technique (NFT), the most commonly used system for hydroponic lettuce. The growing environment for the crop can also affect the persistence of plant residues. These issues may result in the presence of plant residues after the withholding period, even if the pesticide was applied correctly.

The compounding effect of multiple applications of pesticide in lettuce was demonstrated by Sances et al (1993). They showed that multiple applications of methomyl, at short intervals, in field grown head lettuce significantly increased residues. A similar effect could be expected in a hydroponic system if the chemical is present in the nutrient solution and is continuously being recirculated.

The protected environment of the greenhouse can lead to pesticide residues persisting in crops. For example Aplada-Sarlis et al (1994) and Garcia et al (1997) found from trials in hydroponic tomato crops, that procymidone and methomyl are more persistent than the prescribed withholding period would suggest. These studies were conducted in a greenhouse and may have protected the chemical from degradation due to wind, rain and ultraviolet radiation.

Management strategies to minimise pesticide residues

There are a number of management strategies which can be used to minimise pest and disease problems and avoid pesticide residues in hydroponic crops, especially lettuce.

- **Keep the farm clean**

Hygiene is a critical part of managing pests and diseases and a clean farm usually has less pest and disease problems. Keep the farm free of weeds and carefully dispose of diseased plants and old plant matter.

- **Avoid calendar spraying**

Calendar spraying is when pesticides are applied on a schedule without considering the actual presence or extent of pests and diseases in the crop. This practice can result in pesticides being applied when they are not needed and can increase pest and disease resistance.

- **Monitor pests and diseases**

Monitoring means regularly checking your crop for pests and diseases. Monitoring can be done visually by carefully checking plants for the presence of pests and disease. Additional tools such as sticky traps can also be used to check for the presence of specific pests. Regular monitoring ensures problems are found early, making control easier and saving you time and money.

- **Use pest and disease thresholds**

The presence of a pest or disease does not automatically mean financial loss. In some situations, the cost of applying pesticides may be greater than the loss if no action was taken. The level of damage from a pest or disease that can be tolerated before an economic loss will occur is called the economic injury level. This level is the point at which the economic loss from the pest or disease is equal to the cost of taking action.

The point at which a control measure is needed to prevent economic loss is called the action threshold. For some crops action thresholds for certain pests and diseases are available. If there is no recommended action threshold then you need to use your own experience to develop them and make decisions. By using action thresholds you can more accurately time pesticide applications and the number of applications may be reduced. This can also reduce the risk of pesticide residues.

- **Choose the right control measure**

An integrated approach to pest and disease management involves utilising a combination of control measures. Controlling pests and diseases can be done using cultural, biological and chemical measures. There are a wide range of beneficial insects commercially available to control pests. They can be used in conjunction with pesticides but the choice of pesticide is critical to ensuring that these natural enemies survive. Where possible choose pesticides that have a low impact on beneficial insects.

- **Use separate production systems**

The way in which a hydroponic system is set up can have a big impact on reducing the risk of residues. One of the biggest risks for hydroponic crops is having different aged plants using the same nutrient solution, particularly if it is a recirculating system. This can result in the pesticides applied to one crop being circulated through the nutrient solution and impacting on other crops at different growth stages. Therefore the withholding period for any pesticide used, should be observed for all of the plants growing in a single hydroponic system not just the plants to which the chemical was directly applied.

Setup the production area using multiple separate systems. Although this increases the initial set up cost it allows you to manage batches of plants separately. This is particularly valuable in managing root diseases especially when planting out new transplants. Transplanting young plants into a system containing older plants already infected with root diseases almost always results in high mortality of the younger plants and significantly affects growth rates. Another advantage in having multiple production systems is that it allows you to shut down small sections for cleaning and maintenance without disrupting overall production.

- **Prevent spray drift**

Preventing spray drift between young and old plants and different crops is also critical in reducing the
risk of pesticide residues. Make sure there is adequate protection (i.e. screens and windbreaks) between production areas to reduce spray drift onto non-target plants.

- **Increase the Withholding Period (WHP)**

Increasing the recommended withholding period is one way hydroponic growers can reduce the risk of pesticide residues. You need to be confident that your product does not exceed the maximum residue limit (MRL) for the chemicals you use. Testing your product for residues will help you determine if the recommended withholding period needs to be increased for your method of production.

- **Consider the crop environment**

Be aware that residues on crops grown in hydroponics, inside a greenhouse or under shade cloth, are likely to breakdown more slowly than outdoor crops exposed to wind, rain and ultraviolet radiation. Another consideration is the reuse of hydroponic substrates. If substrates are reused for a number of crops these also have the potential to exacerbate pesticide residue problems. It is important to take into account the crop environment in deciding on a pesticide management strategy for your farm.

- **Dump the nutrient solution**

Dumping the nutrient solution following the application of some pesticides is another strategy to ensure pesticides do not get into or remain in the nutrient solution. This is not always practical but could be considered.

More information

More information on using farm chemicals is available from the series *Spray Sense – safe and effective use of farm chemicals*. The series is available on the NSW DPI website at www.dpi.nsw.gov.au.

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