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NEUTRALISING PESTICIDES IN RECIRCULATING WATER SYSTEMS WITHIN A PROTECTED CROPPING SYSTEM

FINAL REPORT

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Purpose of the report

This scoping study aims to explain why pesticide residues issues occur more frequently in high-value lettuce and Asian greens grown in protected cropping (PC) and hydroponic systems than in lettuce from traditional soil-based production. The study addresses causes and backgrounds, and provides practical data and information obtained from three commercial PC growers in QLD, NSW and VIC.

Funding Source:
This project has been funded by HAL using the Vegetable Industry levy and matched funds from the Australian Government.

Collaborating Institutions: HAL & AusVeg - Protected Cropping Working Group

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Contents

List of abbreviations

AI	Active Ingredient
AHGA	Australian Hydroponic and Greenhouse Association
EC	Electrical Conductivity
APVMA	Australian Pesticides and Veterinary Medicines Authority
F&D	flood and drain
FSANZ	Food Standards Australia New Zealand
HCCAP	Hazard Analysis Critical Control Point
IPM	integrated pest management
LV	low-volume
MRL	Maximum Residue Limit
NFT	nutrient film technique
PC	protected cropping
pH	acidity
PCA	Protected Cropping Australia
PTC+	name of a training facility for greenhouse technology in the Netherlands
ULV	ultra-low-volume
UV	ultra violet (light)
BIORATIONALS	have fundamentally different modes of action and consequently, lower risks of adverse effects from their use and have very limited or no affect on non-target organisms

Media Summary

Violation of the Maximum Residue Limit (MRL) or pesticide residue non-compliance is the second most important factor that can cause product to be rejected by the major retailers, after produce quality.

A scoping study was initiated to seek explanations for the fact that pesticide residue issues can occur more often in lettuce grown in greenhouses and/or hydroponic systems, than in field-grown lettuce. Practical data were collected with cooperation of three commercial growers (in QLD, NSW and VIC) who use Protected Cropping (PC) and/or hydroponic systems.

A consideration is the MRL, which is used to assess if a residue is excessive. MRLs are established for pesticides across a range of crops and production methods. In Australia only few pesticides have special registration and a set MRL for PC/hydroponics lettuce. A Pesticide that is not registered for lettuce using this growing method would have no MRL. In this situation a zero (or very low) tolerance would apply and any amount of residue detected would lead to an MRL violation.

Residue issues are partly due to differences between greenhouse and field production. Pest and disease occurrence can be higher in PC/hydroponics due to longer growing season and more intensive production. This triggers higher use of pesticides because crop cycles are shorter in PC/hydroponics than in the field. In a field situation pesticides may also be washed off by rain or broken down by UV radiation, while in a greenhouse there is no rain and less UV. PC-grown lettuces are also harvested as whole plants unlike field grown lettuce, where the outer leaves (with potential residue) are removed during harvest. Therefore there is more chance pesticide residues would not be broken down completely at harvest time in PC/hydroponics.

The reputation of the PC/hydroponic industry is at risk when residues are found repeatedly on produce. This may cause commercial damage. It is crucial to seek improvements in relation to pesticide use, residues, consumer safety and waste management. This study recommends to the industry to considerably reduce the reliance and use of pesticides in greenhouses and/or hydroponic systems. Methods are employing advanced spray technology and applying elements of Integrated Pest Management (IPM), such as cultural practices, intensive scouting and optimal climate control. The latter is a strong benefit of growing in a greenhouse.

Technical Summary

The reputation of the Protected Cropping (PC) and/or hydroponic industry is at risk because pesticide residues are found repeatedly on high-value lettuce and Asian greens produced in these growing systems. Violation of the MRL (Maximum Residue Limit) or pesticide residue non-compliance is the second most important factor that can cause product to be rejected by the major retailers, after produce quality. Poor reputation of the industry may cause commercial damage.

A scoping study was initiated to seek explanations for the fact that MRL violation occurs more often in crops grown in greenhouses and/or hydroponic systems, than in those grown in the field. The study was funded by Horticulture Australia with funds from the Vegetable Industry Levy, matched by the Australian Government. Practical data were collected with cooperation of three commercial growers (in QLD, NSW and VIC) who use Protected Cropping (PC) and/or hydroponic systems.

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Apart from that, residue issues are partly due to differences between greenhouse and field production. Pest and disease occurrence can be higher in PC/hydroponics due to a much longer growing season and more intense production, which may trigger more spraying. Because crop cycles are shorter in PC/hydroponics than in the field, less withholding time is available between spraying and harvest. So there is more chance any pesticide residue is not broken down completely at harvest time. In the field any pesticide is washed off by rain or broken down by UV radiation, while in a greenhouse there is no rain and less UV. Also, in field-grown lettuce the outer leaves (with potential residue) are removed, whereas in PC-cultivation whole lettuces plants are harvested.

Observations and interviews at the three PC enterprises yielded valuable data that can be used as benchmark. A variety of pesticides was used, sometimes off-label. Each of the three growers said they incorporated Integrated Pest Management (IPM) technologies in their production process. But after further discussion, each grower said that in pressure situations they often take the easiest options. Each grower had invested very little to modernise the sprayers, and they found their current application systems adequate. Each used the 'shot-gun' approach (blasting pesticides onto the crops) rather than finesse and careful consideration. All participating growers did not view any changes as necessary, because their current investment in pesticides appears small, and therefore cost saving in this area may not be substantial.

This study recommends to the industry to considerably reduce the use of pesticides. Methods are employing advanced spray technology and applying elements of Integrated Pest Management (IPM), such as cultural practices, intensive scouting and optimal climate control. The latter is a strong benefit of using a greenhouse. Advanced spray technique is based on treating the enclosed space, which allows using low-volume or ultra-low-volume of pesticide.

Recommendations to the industry:

- aim for improvement in issues around pesticide registration, off-label use, crop MRLs and listed MRLs for Protected Cropping (PC) and hydroponic growing systems.
- aim to have a range of pesticides available (with different Active Ingredients): try to get more pesticides registered for application in PC/hydroponics, and avoid the development of resistance.
- make it the industry primary goal to significantly reduce pesticide use, and develop ways to achieve this goal
- investigate the pathways of how pesticide residues end up on (or in) the produce
- based on known pathways, try to stop residue to occur on (or in) the produce
- improve pest and disease control by incorporating elements of IPM, reduced-risk pesticides, biological agents (if possible), optimal climate control or biorationals
- invest in modern spray technology that is commonly used in the advanced greenhouse industry overseas, which is based on low volume or ultra-low-volume pesticide use (or high-volume if not in PC
- investigate potential remediation techniques for residues in nutrient solution, e.g. by using ozone sterilisation systems (if this is relevant)
- generate baseline data of lettuce and other crops including chemical residue analysis data
- study sustainable production systems used overseas and subsequently design industry standards and norms for Australia.

Introduction

General

Industry

Australia is the biggest producer of hydroponic lettuce and Asian green vegetables in the world, and 29% of all registered Australian vegetable farmers are in some form of protected cropping (data AusVeg & AHGA, 2009).

Maximum Residue Limits (MRL) violations

The Australian protected cropping (PC) industry faces regular scrutiny by various sectors of the market place. Maximum Residue Limits (MRL) violations are reported regularly. Pesticide residue non-compliance is the second most important factor that can cause product to be rejected by the major retailers, after produce quality.

In 2009 a national forum was convened to address these violations. The forum was composed of growers, advisors, regulators, pesticide companies, HAL & AUSVEG representatives and was chaired by the Chairman of Protected Cropping Australia (PCA). An outcome from this forum was awareness that MRL violations occurred more in some protected growing systems than in traditional soil growing.

Scoping study

The industry forum decided to do a preliminary investigation or ‘scoping study’ into PC systems to identify targeted areas for research, and find the reasons for this increased MRL violation occurrence. Issues that need addressing are: water use, waste management, pesticide use, pesticide residues, diseases and insects management, application technology, applicator, picker and consumer safety and environmental impact.

Participants

PCA has identified three successful PC lettuce growers that have agreed to partake in the data generation and collection process. They are located in Bundaberg, QLD; Western Sydney, NSW and Bellarine Peninsular, VIC. The information on change obtained from these 3 PC sites will be used to then take to the wider PC industry. Baseline data will be generated from commercial size trial sites.

Protected cropping (PC) and hydroponic growing system

Protected cropping (PC) and/or hydroponic systems are significantly different from traditional soil vegetable cultivation in a number of ways:

1. Micro-climate: PC systems allow for precise control of the microclimate in terms of temperature, humidity, carbon dioxide (CO_2) level and sometimes light (by shading). This allows better control of plant growth, but also of conditions that influence pests and diseases.
2. Radiation level: radiation levels are lower in a greenhouse than outdoor, and can be reduced further by using shade and energy screens. This affects the plants and also reduces the rate of break-down of pesticides.

3. Plant densities: plant populations per m^2 are typically at a higher density in PC systems, often in order of magnitude of at least 100%.
4. Plant varieties: cultivars used in PC/hydroponic systems are particularly bred for these growing methods and often include summer and winter varieties.
5. Yield: Yield in PC/hydroponic system is generally much higher than in field crops, because cropping cycles are shorter and more cycles can be completed in a year
6. Pest & diseases: Incidence of pest and diseases can be different in PC/hydroponics systems than in outdoor in terms of time of the year, frequency, severity, persistence, resistance
7. Spraying systems: spraying techniques and technologies can be quite different (more precise) than in traditional soil growing, due to the enclosed environment and different growing systems
8. Integrated Pest Management (IPM): PC allows application of IPM based on optimal climate control leading to less plant stress. (The use of beneficial insects may not be as feasible in lettuce).
9. Growing systems: hydroponic production systems for leafy greens are usually on raised tables with plants growing in plastic channels, gullies or tables.
10. Growing technologies: PC systems include a wide range of growing systems and techniques, such as Nutrient Film Technique (NFT), flood-and-drain (F&D) as well as cultures on growing media.
11. Root-zone conditions and plant nutrition: Hydroponic systems have nutrient-rich water continuously, or intermittently, flowing past the roots at a controlled rate. This allows for precise control of plant nutrition
12. Harvesting: Lettuce grown in hydroponics are sold with nearly the roots and all leaves attached, whereas from field-grown lettuce the outer leaves (with most of the residue) are removed.
13. Run-off: Also any excessive pesticide will run-off and can potentially enter the root zone water stream and accumulate in the system

It is unknown which of these manifold differences contribute to the occurrence of MRL violations in PC/hydroponic lettuce. This scoping study is to determine what investigations are required to assess and develop a suitable industry management program.

Method and activities

The national industry forum recommended that a scoping study be performed to investigate how MRL violates were related to physical and physiological characteristics of protected cropping (PC) systems, and to look into and the differences of PC cropping systems and traditional soil cultivation. The study consisted of the following elements:

1. Graeme Smith (Graeme Smith Consulting) & Peter Dal Santo (AgAware Consulting) were contracted to perform technical assessment procedures of current system technologies
2. Three separate hydroponic lettuce farms were selected
3. Three different climatic zones were represented in the three farms (tropical, sub-tropical & temperate) to assess potential relation to climate
4. On each farm, a dedicated area of ± 200 – 400 plants can be isolated from the rest of the farm and be equipped with its own irrigation/fertigation system for future study
5. The three farms were assessed individually with regards to plant culture and management practices including climate control, nutrition supply, spray technologies, spray products, etc.

Industry representatives agreed to be involved in this study and to make a part of their farm available for future research. The three representatives are from Bundaberg QLD, Western Sydney NSW and Bellarine Peninsula VIC. It was agreed by the project collaborators to maintain the confidentiality of these three growers to ensure full and frank disclosures and anecdotal evidence of typical current industry practices, such as products used, application rates, frequency & timing, etc.

The three sites had current practices and outcomes recorded. In the near future they may be modified. Practices include water management, pest management, pesticide application, safety issues, application of IPM and sustainable systems.
Graeme Smith & Peter Dal Santo visited each farm to assess its current practices and its suitability for inclusion in a future management project plan proposal to be developed from this scoping study.

Graeme focused on hydroponic production systems and on developing a controlled trial. He aimed to utilize as much as possible the existing technologies at each site and to ensure that industry standards and norms are replicated.
Peter concentrated on using existing registered products, their current sensitivity to MRL violations, and on techniques to apply, measure and assess various products within the hydroponic systems.

Results

In this chapter we present the information that was collected at site visits.

Farm 1 - Bundaberg QLD

Hydroponic leafy/fancy lettuce, oriental and brassica Asian leafy vegetable grower in open air tables. The main markets are Coles, IGA, Food-Works, local shops & some export.

Production system

- Total production system is closed (full recirculation) divided into 2 unique systems producing on open-air tables
- Each open-air tables are composed of 6 - 11 longitudinal gullies (12 m long x 1.4 – 1.6 m wide) with a total of 300 - 400 holes resulting in 21 plants/m²
- Total production capacity is 52,000
- Gullies on tables slope from 0.3 - 0.6 m (± 5 % over 12 m)
- Irrigation flow rate – 1 litre/min, moving to pulse feeding – on for 4 min, off for 12 min (8 – 10 min in summer)
- System has 2 x 8000 litre nutrient/irrigation tanks with 2 x ozone sterilization systems per tank (for pathogen control)
- Plant buffer per system ± 310 ml per plant
- EC range of 1.3 – 1.6 for lettuce, and 1.8 for salads
- pH target of 6.2 – 6.3 maintained with Nitric or Phosphoric acid
- Nutrient solution annual temperature range 5 – 36.8 °C
- EC town water supply 0.5 – 1.1 (excess salts controlled by reverse osmosis system), backup dam water of EC 0.3

Cultivation

- Fancy Lettuce, red & green coral, oak and butter-head, oriental mustards (mizuma, tatsoi) and brassica Asian leafy vegetables (bokchoi, pakchoi)
- Produces an average of 9.5-10 crops/year for lettuce & brassicas (6 runs/table & 300-400 centres) and 25-30/year for orientals (11 runs/table & 120 centre's)
- Production timeline: lettuce 3 - 6 weeks, brassicas 2.5 - 5 weeks, orientals 10 - 14 days (all crops take longer to mature in winter)

Seedling nursery

- Grower produces all their own seedlings onsite in vermiculite propagation media
- Timeline from seeding to transplant: lettuce 3.5 - 6 weeks, brassicas 3-7 weeks, orientals 2-4 weeks (all seedlings take longer in winter)
- Seedlings are growing in trays on tables under green shade-cloth (for excess radiation protection)

Diseases
- Botrytis – common, grower uses iodine applied weekly at rates of 2 - 4 ppm
- Downy mildew – common, grower uses iodine applied weekly at rates 2 - 4 ppm
- Sclerotinia – nil
- Anthracnose – rare, uses copper foliar spray as necessary

Insects
- Shore fly and fungus gnats – common, Imidacloprid used in nursery
- Cluster caterpillar – common, uses Permethrin® or Spinosad® in field 1 or 2 times per crop
- Rutherglen bug – common, uses Maldison® or Trichlorfon® 0 – 2 times per crop
- Pesticides used requires a minimum of 2 days withholding period

Herbicides
Grower uses Glyphosate under tables to control all weeds and discarded plants

Residue testing
Grower has residue testing done annually for HACCP certification

Seedling nursery drenching
- Fungus gnats is major problem. Grower uses Azardactrin® or Imidacloprid® as a flood spray over the top of the seedling trays.
- Downy mildew, Pythium and Phytophthora: Metalaxyl® + Mancozeb® as a flood spray over the top of the seedling trays.
- Botrytis: Captans® as a flood spray over the top of the seedling trays.

Spray application

- Tractor mounted 400 litre tank with hanging boom (driven by PTO pump), equipped with 5 directed nozzles (per side) and spraying 2 tables per pass
- Nozzles type TJ60 - 11006VS
- System delivers 400 litre that takes 15 min at 3-4 km/hour for 129 tables (total current tables)
- Each table ± 19 m^2 x 129 tables = 2,450 m^2 = effective dose rate of ± 1,600 litre/ha
- There is an acknowledged issue with correct spray height of spray boom over the top of tables as they are sloping. Sprayer height is set at 300 mm above highest point on tables, which gives double overlap at lowest point on tables.

Farm 2- Western Sydney NSW

Hydroponic fancy lettuce grower in greenhouses with polyethylene roof (4 - 5 m high) with shade cloth and polyethylene walls that can be raised or lowered. The main market for the produce is Woolworths (only).

Production system

- Total production system is closed (full recirculation) divided into 7 unique greenhouse systems, each producing on 30 tables (each fitted with 2 x nursery channels)
- Each greenhouse is 20 x 80 m (1,600 m^2)
- Each table is composed of 8 longitudinal gullies (18 m long x 1.6 m wide) with a total of 1,120 holes resulting in 21 plants per m^2
- Total production capacity is 235,200 lettuce in 7 greenhouses totaling 11,200 m^2
- Gullies on tables slope ± 0.7 m (± 4% over 18 m)
- Irrigation flow rate: 1.5 - 2 litre/min
- System has 7 x 4,000 litre nutrient/irrigation tanks with no auto sterilization systems (manually dosed 40 gram Biowish™ x 3 times week each tank for pathogen control)
- Plant buffer per system ± 120 ml per plant
- EC of 1.2 for lettuce
- pH target of 6.3 – 7.0 maintained with 250 ml/day per tank of Phosphoric acid
- Nutrient solution annual temperature range 0 – 42 °C
- EC town water supply 0.2

Cultivation
- Variety Salanova™ - red & green coral, red & green butter-head
- Produces an average of 12 crops/year for lettuce (8 runs/table & 560 x 25 cm centres for production and 2 runs/table nursery 560 x 5 cm centres)
- Production timeline, lettuce 3-4 weeks (all crops take longer to mature in winter)

Seedling Nursery
- Grower buys in all their seedlings from local nursery
- Delivered seedlings are grown in 2 gullies above production area on tables and transplanted down when suitable maturity size reached

Diseases

- Pythium, Phytophthora, Fusarium, Downy mildew, Big vein (all rare)
- Botrytis was minor in 2010 (not treated)
- Sclerotinia was a problem, grower used Boscalid® drench for past 5 years (up to 70 % loss when not used)

Insects

- Plague thrips – minor
- Western flower thrips – major, some resistance to Spinosad®, but Spinosad® is still used for WFT and other pests; drench with Spirotetramat® plus 1 or 2 foliar applications from October to April, some control with Emamectin® when used for other pests
- Heliothis – minor, use Spinosad® and Emamectin®
- Rutherglen bug – rare, uses Maldison®
- Aphids – rare due to Spirotetramat® drench

Herbicides

Grower uses Glyphosate + Carfentrazone® 4 x per year under tables and around property boundary to control all weeds and discarded plants

Residue testing

Grower has major concern with FSANZ Food Standards Code MRL. He has all his products for Woolworths tested for residue, but has not received any reports. His last violation was with Dimethoate 5 years ago.

Seedling nursery drenching

- Nursery uses none number varieties, and treats seedlings with Azoxystrobin® (broad spectrum fungicide) and Pirimicarb® (aphids)
- Grower drenches seedlings with Boscalid® (against Sclerotinia and Botrytis) on-farm prior to planting, (rate 250 gram per 500 litre for 57,000 seedlings) until there is run-off

Spray application

- Tractor mounted 600 litre tank with gun driven by PTO pump and air-assisted with mounted nozzles (pressure 7 – 8 bar)
- Cannot drive thru greenhouses, therefore sprays from laneways along each greenhouse and directs the spray inside (applications from either side of greenhouse (raises walls) or double sprays (up and back)
- System delivers 200 litre per greenhouse for 30 tables
- Effective dose rate of ± 1,250 litre/ha
- Grower uses a professional crop scout fortnightly

Farm 3 - Bellarine Peninsula VIC

Hydroponic leafy and fancy lettuce grower in greenhouses with polyethylene roof (3-4 m high) with polyethylene walls (some walls can be raised or lowered). Main market is Wholesale markets in Melbourne, Sydney, Brisbane and Adelaide and Coles.

Production system

- Total production system is closed (full recirculation) divided into 9.5 unique greenhouse systems, each producing on 38 tables
- Each greenhouse is 12 x 90m (1,080 m^2)
- Each table is composed of 2 x 8 longitudinal gullies (6 m long x 1.6 m wide), feeding into a common centre drain with a total of 400 holes resulting in 14 plants per m^2
- Total production capacity is 144,000 lettuce in 9 greenhouses totalling 10,260 m^2
- Gullies on tables slope ± 0.3m (± 5% over 6 m)
- Irrigation flow rate ± 0.4 litre/min
- System has 9 x 5,000 litre nutrient/irrigation tanks with auto Ozone sterilization systems (5mg/8hours), also manually dosed 70 gram Sporekill® 2-3 times per week each tank for pathogen control (increased to 200 ml when Pythium & Phytophthora suspected)
- Plant buffer per system ± 330 ml per plant
- EC range 0.9 - 1.6 for lettuce (manually dosed in late afternoon)
- pH target of 6.2 maintained by dosing day & night per tank with Phosphoric & Nitric acid
- Nutrient solution annual temperature range 6 – 38 °C
- EC town water supply 0.2

Cultivation

- Variety Salanova™™ - red & green coral & oak, butter-head, mignonette & baby cos lettuce, pakchoi and Chinese broccoli
- Produces an average of 11 crops/year for lettuce
- Production timelines: lettuce 3.5 - 5 weeks in summer & spring, and 6-7 weeks in late autumn & winter
- Production timeline: pakchoi 2.5 - 3 weeks in summer & spring and 5 weeks in late autumn & winter
- Also trialling Chinese broccoli

Seedling nursery

- Grower buys in all their seedlings from NSW nursery
- Seedlings when transplanted are 5-9 weeks old. All seedlings take longer in winter. Grown on course pine bark
- Seedlings are dropped into holes when transplanted. Root ball holds pine bark intact for life of crop

Diseases
- Botrytis – common, can cause 2-5% loss if not treated with Boscalid®
- Downy mildew – rare
- Sclerotinia – common, can cause 2-5% loss if not treated with Boscalid®
- Pythium & Phytophthora – commonly adds Sporekill® to holding tanks to kill diseases. Rare to get these diseases in crop therefore grower considers he has very low disease and insect pressures
- Also believes in controlling mould and algae in channels to limit disease pressures

Insects
- Green peach and Currant lettuce aphid – nil as seedlings drenched with Imidacloprid®

Herbicides
Grower uses Glyphosate + Carfentrazone® monthly under tables to control all weeds and discarded plants

Seedling nursery drenching

- Seedlings drenched with Boscalid® (200 ml per 600 litre for 40,000 seedlings - Sclerotinia and Botrytis) + Imidacloprid® (20 ml per 1000 seedlings - aphids) by seedling supplier before leaving Sydney, adds 77 ml/1000 plants
- Has found that Imidacloprid® at 35 ml/1000 seedlings causes residue violations
- Boscalid® for Botrytis and Sclerotinia – very effective
- Imidacloprid® as a seedling drench for aphids – very effective, not used on Nr varieties

Spray Application Technology

- Tractor mounted 400 litre tank with gun driven by PTO pump and air-assisted with mounted nozzles (3 x different angles)
- Cannot drive thru greenhouses, therefore sprays from laneways along each greenhouse and directs the spray inside
- Also uses backpack spray system for hot-spots when required
- system delivers 400 litre per 9.5 greenhouses, each with 38 tables
- effective dose rate of ± 390 litre/ha

Characteristics of the three participating farms

Assessment of the three farms shows significant variations in most characteristics (dimensions, management, irrigation strategy, fertiliser strength, flow rate, slopes, etc) as follows:

Farm characteristics - Neutralising Hydro Pesticides Project - VG09121			
	Western Sydney	**Bundaberg**	**Bellarine**
m^2	1600	2450	1080
number of greenhouses	7	0	9.5
total m^2	11,200	2,450	10,260
holes/table	1120	400	400
tables/greenhouse	30	129	38
holes/greenhouse	33,600	51,600	15,200
plants/m^2	21.0	21.1	14.1
total holes	235,200	51,600	144,400
tank litre	4,000	16,000	5,000
ml/plant	119	310	329
litre/spray	1400	400	400
eff litres/ha spray rate	1,250	1,633	390
EC	1.2	1.3 - 1.6	0.9 - 1.6
pH	6.3 - 7	6.2 - 6.3	6.2
litre/min flow rate	1.5 - 2	1.0	0.4
m gulley length	18	12	6
% gulley slope	4	5	5
annual solution temp range	0 - 42	5 - 37	6 - 38
average crops per year	12	10	11

Application technology

1. Application technology

In general the application technology used by the growers visited was 'low-tech', namely boom-sprayers and blowers.
The technology was used reasonably effective in their situations. Each grower incorporated plant pest management techniques that reduced the reliance on pesticides. This is assisted by practices such as:

- Quick turnover of crops
- Clean growing environments
- Relatively low pest pressure crops
- Sound production systems
- Healthy plants

It is anticipated that significant improvement to spray results can be realized with more suitable and professionally designed equipment as shown above.

2. Application techniques

Two growers used tractor mounted air-assisted 'blowers', one fitted with a 'gun with nozzles' and the other with a 'mister'. The greenhouse geometry and equipment layout was suited to maximize lettuce production, with multiple growing tables at varying levels. Due to internal posts and piping, the growers could not drive through the crop. Therefore they had to propel the spray from the laneway outside the greenhouse for 12 - 20 m into the greenhouse to cover the entire crop. This is a completely haphazard system that is effective more by good fortune than science.
The QLD grower had outdoor growing tables so was able to drive through the crop. He used a homemade boom setup, but the equipment and table layout meant that application was less than ideal.

3. Application effectiveness

According to the growers, the current application systems all appear to be adequate. Each grower has invested very little to maintain or modernise the sprayers. All growers were using the 'shot-gun' approach (blasting pesticides onto the crops) rather than controlling plant pests with finesse and careful consideration. None of them was make use of the advantages that greenhouses offer, namely to use fumigation with Low Volume or Ultra Low Volume spraying.

4. Application measurements and pest thresholds

None of the growers visited routinely measured their application effectiveness (such as using water sensitive papers) or checked whether pest number thresholds had been exceeded (such as using sticky pest traps).

Residue non-compliance

1. Residue non-compliance (refer Agrisearch 2008 report)

HAL-funded project VG06111, conducted by Agrisearch Services in 2006-2008, investigated the residues in PC vegetables, including lettuce. It was found that the application of (registered) pesticides can lead to non-compliance with the APVMA MRL and the FSANZ Food Standards Code. This is because in some cases, the pesticides are registered for field crops only and for certain lettuce types only (e.g. head lettuce only). The study found that the withholding period for some pesticides had to be extended from one or a few days to 7-28 days to comply.

Inspection of the application equipment and techniques of the three growers showed there is a high risk of residue non-compliance. This happens if a persistent pesticide is sprayed onto the crop and inadequate time is allowed for the residues to dissipate before harvest.

The risk of residue non-compliance is increased by the choice of the application technique:

- With the blowers: risk of higher residues on lettuce closer to the sprayer.
- With the boom-spray: risk of higher residues on lettuce where the spacing between the tables and boom height is smallest.

Explanation for residue non-compliance

Pesticide residue non-compliance occurs more frequently in leafy lettuce from PC than form soil cultivation, both in state and national monitoring. There are several reasons for this:

- Greenhouse/hydroponic lettuce has to comply with MRL, or in case no MRL is set with nil residues
- In PC lettuce the breakdown of pesticides by natural environmental factors (e.g UV light) can be impeded
- Most leafy lettuce varieties have a shorter growing period, so it is harder to comply with the withholding period as per label recommendations.
- Many pesticides for lettuce are very old and moreover the application method and withholding period refer to field-grown head lettuce.
- In field-grown lettuce the outer leaves (with most of the residue) are removed whereas in PC/hydroponics the whole lettuce plants, including roots is harvested.
- Regulatory agencies increase the scrutiny on leaf lettuce as residues are often an issue.

Discussion of observations at the three farms

Here follow some observations at the three participating growers:

1. Pesticide degradation on the plants (PC crops versus field-grown crops)

Degradation of pesticides on the plants can be different in protected crops versus field-grown crops, and can also be different depending on pesticide, crop, season, etc. Hence more residue can be found in saleable produce from protected or soilless cultivation than from outdoor cultivation, due to:

- Less UV (greenhouse covers are generally opaque to UV radiation)
- Less UV due to seasonal effects (crops grown in winter receive lower UV level)
- Less rainfall
- Less wind or air movement
- Less fluctuations in climate
- Less microbial breakdown
- Softer plants (potentially if growing conditions are not optimised)

2. Pesticides in the solution

Some pesticides, e.g. imidacloprid®, methomyl® and chlorpyrifos® can enter the irrigation solution, for instance via the following pathways:

- wash off treated seedling planted in a cell
- wash off the leaves into irrigation solution (by rainfall or overhead irrigation or run-off)
- enter the irrigation solution via an empty cell.
- circulate through the plant and move into the irrigation solution

Although the volume of pesticide transferred via these pathways is very small, it has led to some residue non-compliance. In some cases these pesticides can remain active in the irrigation solution, and can be taken up by the next crop.

3. Pesticides removal from nutrient solution

It is possible to remove pesticides from the irrigation solution by water treatment, especially with ozone technology. Two of the three participating growers had ozone technology, primarily for disease and algae control in the irrigation water. These systems may work on neutralizing pesticides if the dose and exposure is suitable. In these cases the growers were not using ozone for this purpose.

4. IPM adoption and (non-)compatibility

Integrated Pest Management (IPM) does not only refer to the use of biological control agent, but also to cultural, mechanical and environmental practices used. (Note that biological control agents may be undesirable in lettuce).

Each of the three growers talked about their support for IPM and said they incorporated IPM technologies in their production systems such as:

- they selected seedlings of a specific variety that was less sensitive to diseases
- in some cases used seedlings that were pre-treated with pesticides
- had clean growing environments
- used pesticides on the crops only when necessary (all growers)
- used crop scouts (one grower)
- using pesticides that were IPM compatible

But after further discussion with each grower, they told that in pressure situations for pest control they often took the easiest options. Some of the pesticides used were not IPM compatible, for instance:

- Imidacloprid® agains aphids and shore fly
- Permethrin® against caterpillar
- Maldison® against Rutherglen bug
- Trichlorfon® against Rutherglen bug

5. Solution pathology and water treatments

A recent HAL project (The National Greenhouse Waste-Water Recirculation Project – VG09073) was designed to deliver necessary skills to greenhouse vegetable growers in converting their current free-drainage (open) systems to full recycling (closed) systems.
Part of this project was to invite growers to participate in an investigation into any potential pathology issues related to recycling waste-water including assessing the efficacy of various sterilisation systems.

The data collected in the grower database revealed a significant diversity of sterilisation systems utilised in the industry Australia wide and included: UV, ozone, hydrogen peroxide, slow biological, iodine, reverse osmosis, ultra-filtration, chlorine dioxide and beneficial microbes, etc.
At time of writing, NSW DPI Pathology have not completed their trials, therefore there is no final report from them. However some trials that have been completed indicate a significant lack of efficacy in some of the treatment systems. This non-performance could be due to less than ideal management by the grower or point to failings in the technology itself. Len Tesoriero is requesting follow-up samples from these enterprises to ensure testing and sampling integrity and will provide direct feedback to assist each grower affected.

These laboratory tests were designed to measure only the presence of common crop pathogens (e.g. Pythium, Phytophthora, Fusarium, etc.) and not chemical pesticide residues. Therefore it is not known at this time whether sterilisation systems potentially have a neutralising effect on pesticides. The systems that work on an 'oxidation' principle will probably have some efficacy in this area.

6. Water treatment and pesticide neutralisation

Water treatment is the most direct method to neutralize any pests in the nutrient solution. Obviously, water treatment is applied primarily for reducing pathogens, such as spores of fungal diseases, e.g. Fusarium, Pythium and Phytophthora. This reduces the need for pesticides and leads to stronger plants due to less external stresses.

7. Growers' viewpoint

There are not many practical solutions for real-life pests in leafy vegetables. Pesticide residue non-compliance is the second most important factor that can cause product to be rejected by the major retailers, after produce quality. Nevertheless, the three participating growers perceived pesticide use as relatively minor component of the production process, and found the emphasis on water treatment and pesticide neutralisation not necessary.

General discussion

The wider picture & pathways

The title of this report refers to a very specific topic *(Neutralising pesticides in recirculating water systems within a protected cropping system)*. Worldwide, only a limited number of solutions are known for this problem. However, this topic is part of a much wider issue, and thus the solution has to come from a much broader approach. Table 1 gives an overview.
It starts with the Maximum Residue Limits (MRL). How high or low is it? Is it realistic for Protected Cropping (PC) / hydroponic growing systems? Or is it a default level because the pesticide was used 'off-label' (see explanation below). It is worthwhile to investigate topics such as pesticide registration, off-label use, default MRLs and listed MRLs in relation to PC and hydroponic growing systems.

Pathways
It can be questioned if the title of this report addresses the real problem. Do the MRL violations relate to nutrient solution or to the produce? Does residue come from the nutrient solution? If so, how does the residue get into the nutrient solution? Can it be added deliberately, for instance a systemic pesticide used as a 'drench'? It will be useful to understand how pesticides end up in the nutrient solution as well as in (or on) the produce.

Maximum Residue Limit (MRL): how is it determined?
MRLs for Australia are established by Food Standards Australia New Zealand. Each pesticide comes with a label containing 'directions for use'. These specify details such as the amounts to be used, application technique and required waiting time. If a pesticide is required to be used in a different manner than described on the label, then it is called 'off-label use' and a permit is required for this use for most Australian states. Permits exist in Protected Cropping (PC) and hydroponic cultures (see examples below). In case of off-label use, a Maximum Residue Limits (MRL) is 'set' just as in a registered use. The latter is often at a very low amount, which can easily be exceeded. Hence off-label use can easily lead to MRL violations.

Off-label use
Pesticide registration differs between states. Most pesticides are first registered for use in major crops and thus the 'directions for use' on the label were initially for the major crops only. Many pesticides were later registered for smaller crops by the manufacturer. Where there is no registered use, but growers require access to the pesticide, the APVMA allows for minor-use permits to be issued for specific crops and target pests. Conditions associated with permits are the same or similar to registered labels. For minor-use permits in PC and hydroponic crops in Australia, data needs to be provided from crops grown in PC and hydroponic situations.
. In countries with a large greenhouse industry, several pesticides are registered particularly for use in PC and hydroponics as well. The label is then adjusted to include directions for application in these particular growing systems.

Registration in Australia
In countries with a small or young PC industry, such as Australia, it is probably not economically feasible yet for pesticide manufacturers to register their pesticides for use in minor crops or in particular growing systems such as PC or hydroponics.
If an Australian grower decides to use a pesticide in a greenhouse and/or hydroponic system, and if the pesticide was not registered in Australia for such use, then this use may be

regarded as off-label use. In that case it is likely that the zero tolerance or a low MRL will be applied, and that an MRL violation could occur.
Here are two examples of off-label use. Some pesticides are made to kill fungal root diseases in field-grown crops. Some hydroponic growers may decide to add such pesticides to the nutrient solution. If this is not according to the label, it may be regarded as off-label use.

Systemic pesticides are absorbed by the plants, and kill insects that suck up the poisoned plant sap (or kill fungi before they penetrate into the plants). If a grower adds this pesticide to the nutrient solution while this way of application is not described on the label, then also this can be regarded as off-label use.

Pesticides availability and IPM
It is a serious concern if the Protected Cropping / hydroponic industry has insufficient pesticides available, or actually insufficient 'active ingredients' (AI). When using pesticides, it is good to alternate between different AIs. Otherwise a pest or disease will develop resistance against that particular AI. This results in fewer pesticides being available.
IPM (Integrated Pest Management) is very important in this respect. The use of IPM means that pesticide can be used much less. This is good for food safety and it delays the occurrence of resistance, so that the pesticide can have a longer effective lifespan. IPM may comprise the use of biological control agents (but is not desirable in lettuce) in combination with cultural practices such as climate control (which is feasible especially in greenhouses!). It has limitations and cannot always offer the solution to all pest or disease problems, so pesticide will remain necessary. Obviously pesticides must be used according to Good Agricultural Practice.

Application technology
Many PC growers use simple application technology that was designed for use in the field. They don't invest in high-tech precision application technology based on fumigating the enclosed space (the greenhouse). These precision techniques require much smaller quantities of pesticides, e.g. Low Volume (LV) and Ultra Low Volume (ULV) techniques. Conventional field sprayers use more pesticide and therefore causes much more residues. In fact, reducing residues starts with reducing the amount of pesticides used.

Solution for partial problems
Table 1 shows that the problem can be broken down in partial problems. The third column shows prevention/mitigation, but most of them are not adequate solutions.
Residue on the produce is probably the real problem. This can be mitigated by overall reduction of pesticide use (see next paragraph). It can also be reduced by applying waiting time between spraying and harvesting, but this harms the produce quality and disturbs the scheduling of the production cycles. In theory, produce can be washed or exposed to UV radiation to remove the residue, but this is always practical or desirable.
Residue on the plant is very dangerous for the workers, so work must be delayed until the residue has disappeared. Otherwise gloves and protective clothing must be worn. Residues on the plant may end up in the nutrient solution. How to mitigate this: see further.

Overall approach: reducing pesticide use
The overall approach to reduce residues is by reducing the amount of pesticide used. This can be achieved by using precision technology which is commonly used in the advanced greenhouse industry overseas. For instance the enclosed space of a greenhouse can be treated, which requires very low volumes of pesticides. Perhaps also the frequency of spraying can to be reduced. Using biological control agents (as part of IPM) is not feasible, as

it is undesirable that pests and control agents are present on the produce. A good method is creating conditions in the greenhouse that are favourable for the plants and unfavourable for pests and diseases. Good growing conditions make plants stronger & less susceptible for pests and diseases. Fungal diseases can be controlled by optimal humidity control to avoid condensation on the plants. These are advantages that PC offers over field cultivation. Obviously pesticides must be used according to Good Agricultural Practice.

Neutralising pesticides in recirculating water systems

Worldwide there are few solutions for neutralising pesticide in the nutrient solution. One technology that works well is burning (oxidising) the residue by a thorough ozone treatment. This requires good specialised equipment, otherwise the ozone can do a lot of damage to the plants and even to humans.

There are no other techniques for removing pesticides from water that are currently feasible for horticulture. Other options are discharging the nutrient solution with the pesticide in it, but this may cause severe damage to wild-life in the environment (paddock, wet-land, stream or waterway) where the nutrient solution is dumped. Another way is storing it and exposing it to natural UV from the sun, but this is often not practical.

Table 1. Schematic representation of the wider picture: side issues and broad approach of MRL violation. The issue mentioned in the title (*Neutralising pesticides in recirculating water systems within a protected cropping system*) features in cell D-f and F-c

PROBLEM	POSSIBLE CONSEQUENCE	PREVENTION / MITIGATION	METHODS
(A) Maximum Residue Limit (MRL) violation in Protected Cropping (PC) and/or hydroponics		(a) Registration of pesticide for use in PC and/or hydroponics, to avoid that pesticide is used 'off-label'	
		(b) Setting a realistic MRL for PC and/or hydroponic crops	
(B) Residue on produce		(a) Reduce pesticide use	optimal climate control, cultural practices, IPM, advanced spraying technology, soft agents
		(b) Use precision application	
		(c) Apply waiting time *	Delay harvesting
		(d) Wash the produce *	
		(e) Apply treatment e.g. expose to air or UV **	
(C) Residue on plant	(1) May end up on produce	See above (B a, b, c, e)	optimal climate control, cultural practices, IPM, advanced spraying technology, soft agents
	(2) May wash into nutrient solution and be discharged	See below (D & E)	
	(3) May have health consequences for workers	(a) Avoid working in greenhouse after spraying, especially when crop is wet (b) Use protection	(i) Timing: spraying in late afternoon (ii) Postpone work if possible (iii) Use protective clothing and masks
(D) Residue in nutrient solution: systemic pesticides deliberately added to the nutrient solution ('drenching')	Pesticide in nutrient solution is gradually taken up by plants and ends up in the produce. Some of it will end up in discharge water.	(a) Adhere to recommendations as per label for hydroponic crops in PC (incl waiting time)	
		(b) Reduce the use of systemic pesticides ('drenching')	optimal climate control, cultural practices, IPM, advanced spraying technology, soft agents
		(c) Extend the waiting time **	Delay harvesting
		(d) Dilute the nutrient solution	
		(e) Dump the nutrient solution	

		(f) Neutralise the pesticides by water treatment (e.g. ozone)	
(E) Residue in nutrient solution: non-systemic pesticides have landed in the nutrient solution		See D c-f.	
(F) Residue in discharge water (systemic and non-systemic)	Pollution of wet lands or water ways	(a) Reduce pesticide use	optimal climate control, cultural practices, IPM, advanced spraying technology, soft agents
		(b) Reduce dumping	(i) Avoid build-up of sodium (ii) Provide optimal nutrients (iii) Reduce build-up of root exudates
		(c) Neutralise the pesticides by water treatment (e.g. ozone) before discharging	

* This has an adverse effect on produce quality

Technology transfer

Industry Adoption

The PC Industry is actively searching for and advocating for change in its management practices and options to control plant pests and diseases, evidenced by the formation of the pesticides residue forum.

Without these, continued access to the most lucrative markets will be difficult and remote, therefore it is expected that industry adoption will not only be welcomed but also actively pursued.

To assist in this area project outcomes will be communicated across industry forums including PCA, AUSVEG, and various newsletter and periodicals.

Presentations completed

As at time of this report, the following reports to industry have been completed:

1. VIC - Hydroponic Farmers Federation AGM & grower meeting in Yendon
2. WA – West Australian Greenhouse Growers Association grower meeting in Perth
3. TAS – Tasmanian Association of Greenhouse Growers AGM & grower meeting in Campbell Town
4. SA – SARDI Local Growers meeting in March at Virginia Horticulture Centre
5. PCA national 'Soilless Australia' magazine to all association membership
6. SA - PCA national biennial industry conference in Adelaide in July 2011

Presentations to come

1. NSW – at Coffs Harbour & selected Sydney grower meetings with NSW DPI, August 2011
2. QLD – at Bundaberg Fruit & Vegetable Growers Association
3. Practical Hydroponics & Greenhouses (national and international trade magazine)
7. AusVeg national magazine – 'Vegetables Australia'
8. PCA & Graeme Smith Consulting Web sites

Recommendations to the industry

The reputation of the PC/hydroponic industry is at risk when residues are found repeatedly on produce. This may cause commercial damage. It is crucial to seek improvements in relation to pesticide use, residues, consumer safety and waste management. Practical data and information is required to demonstrate that change is possible with benefits to all concerned without loss of production or profit for the grower.

Actions the industry can take:

- advocate to get improvement in issues around pesticide registration, off-label use, default MRLs and listed MRLs for Protected Cropping (PC) and hydroponic growing systems.
- aim to have a range of pesticides available (with different Active Ingredients): try to get more pesticides registered for application in PC/hydroponics, and avoid resistance to develop.
- make it the industry primary goal to significantly reduce pesticide use, and find ways to achieve this goal
- investigate the pathways of how pesticide residues end up on (or in) the produce
- based on known pathways, try to stop residue to occur on (or in) the produce
- improve pest and disease control by incorporating elements of IPM, reduced-risk pesticides, biologicals (if possible), optimal climate control, biorationals,
- invest in modern spray technology that is commonly used in the advanced greenhouse industry overseas, which is based on low volume or ultra-low-volume pesticide use
- investigate potential remediation techniques for residues in nutrient solution, e.g. by using ozone sterilisation systems (if this is relevant)
- generate baseline data of lettuce and other products, including chemical residue analysis data
- study sustainable production systems used overseas and subsequently design industry standards and norms for Australia.

Recommendations for further projects

1. <u>Create a new unit in AgVet farm chemical users training</u>

The unit in its current form is based on traditional field farming techniques and is poorly suited to controlled environment horticulture. For instance, it provides very poor interpretation or adjusted application rates for greenhouse cultivation.
An outcome of this study is to investigate the possibility to update or provide an addendum to the current workbook for best-practice application techniques in greenhouse and hydroponic crops.
A starting point can be to look at the training provided to Dutch growers by PTC+ in Ede in the Netherlands. This is a specialised greenhouse training institute that includes crop-protection training. See an example in Appendix a.
This example covers international best-practice techniques in 'high-volume' (HV) greenhouse spraying. Any future updates would also need to cover low-volume (LV), ultra-low-volume (ULV), sulphur pots and other international hydroponic crop spray systems, etc.

Graeme Smith Consulting has travelled on a number of occasions to PTC+ in the Netherlands as tour leader for growers on various European greenhouse study tours.

2. Provide training in plant management

From our inspection of the three growers, it was evident that nutrients solution, fertiliser program and irrigation strategies were in some cases less than ideal. Poor management practices like these may cause stress on the plants, making the plants more susceptible to infection by diseases and infestation by pests. This leads to earlier and heavier infection by fungal diseases and infestation by pests, and hence earlier and increased use of pesticides. This in turn further increases the stress on the plants. Apart from using more pesticides, the pesticides are possibly less effective in various ways, for instance:

- leaf area can be smaller, so more pesticide spray lands on the gullies
- pesticides are not taken up efficiently when the leaves are damaged or dirty
- pesticides are not fully metabolized
- systemic pesticide are not circulated within the plant as required

All these shortcoming lead to more residues in the plants and in the nutrient solution.

3. Investigate pathways from nursery to post-transplant stage

It is important to know where residues come from. Two of the three growers use seedlings produced by professional nurseries, and the seedlings are treated with fungicides and insecticides. This helps to keep the seedlings healthy and to reduce the need for spraying, especially in the period after transplanting. The third grower produces his own seedlings and treats them with various pesticides. Further research is necessary to investigate the possibility of residue transfer from nursery to production system, as well as the other pathways of pesticide residues.

4. Assess current growers practices

It may be difficult to encourage the participating growers to change their pest management systems, as nothing appears to them as broken at this stage. To change anything would mean a monetary investment. Changes in management do not necessarily cost money, but the growers often do not view them as necessary. The main reason is that their current investment in pesticides appears small, and therefore cost saving in this area may not be substantial. For instance they consider their current application equipment is effective, so they find upgrading this is not essential.

5. Introduce precision pesticide application

It is timely to introduce a new spraying system based on 'precision pesticide application' so we can demonstrate the potential benefits versus the current system. Precision pesticide applications will improve the control of their major problems:

- Diseases e.g. Botrytis, Sclerotinia, Downy mildew
- Pests e.g. Western flower thrips, Shore fly, Fungus gnats, caterpillars, Rutherglen bug

6. Work towards residue compliance

All three growers have a reasonably good understanding of the pesticide residue issues and possible consequences associated with the production of lettuce. Some non-registered use of pesticides was occurring, but obviously used in such a manner that residues at harvest were not discovered. This needs to be addressed.

7. Avoid resistance against valueable pesticides

Frequent use of a particular pesticide leads to development of pests that are resistant to the pesticides. This can lead to resistance, namely that the pesticide has no effect at all on the pest that it was supposed to kill. Growers can reduce the risk of resistance by reducing the amount and frequency of pesticide use, and by alternating between two or more pesticides (Active Ingredients) that address the same pest.

The major pesticide at risk for resistance issues are imidacloprid®, which is used for aphid control in seedlings. It seems that resistance of aphids to imidacloprid® is inevitable. Alternation to other control options or predator insects would be a preferred strategy.

8. Collaboration of growers for trial sites for ongoing assessments

The three participating growers have all said they will collaborate in the future and make available a segment of their farm (isolated tables of ± 400 plants each) for any ongoing trials and product/system assessments.

The location of the three growers is considered suitable as they are spread over three states and are close to other producers and major state centres for training and demonstration purposes.

The isolated tables systems in the three locations would be crucial to demonstrate best-practice principles to industry via optimizing production guidelines.

To maintain trial integrity and protect the remainder of the farming operation, each isolated area would include its own water supply, recirculation tanks and fertiliser dosing system. If required there will be temporary plastic divider curtain put in place to avoid pesticide spray to move from the trial area to the standard product area.

9. Wider project optimization outcomes

A future project aimed at critical assessment of current management systems could focus on the optimal use of the following aspects:

a) irrigation strategy
b) fertiliser strategy
c) plant density
d) spray application equipment
e) spray application techniques
f) growth rates (including covered vs. field production systems)
g) differing UV levels on plant health and colour
h) spray rates in relation to MRL
i) spray rates in relation to disease/pest control
j) spray rates in relation to deleterious plant effects (phytotoxicity, plant damage)
k) use of water sensitive papers to assess application volume and equality of distribution
l) use of sticky traps to assess pest threshold counts and enhance crop scouting
m) assess factors impacting on crop quality and shelf-life
n) improve crop culture and management techniques
o) Measure outcomes of current application practices and pesticide selection
p) Utilise indicator strips for seedling residues and to investigate the accuracy of the pesticide loading compared to label rates that the growers are paying for.
q) Measure mature plant residues from the 3 growers given their unique application systems.
r) Measure nutrient solution residues to determine differences for the pesticides used
s) Introduce new application technology & techniques then re-measure above residues
t) Measure influence of sterilization systems on presence of chemical in hydroponic nutrient solutions

u) Assess product profiles and fit-for-use aspects that will need to be tailored to each grower. (A good reason is needed for them to change as all appears to be currently working even with a risky environment)
v) Identify key indicator crops for trials, namely the most sensitive lettuce/Asian greens varieties (others crops will be required for residue testing)
w) Focus on leafy green products & water systems (NFT, F&D, etc), but communicate flow-on benefits for media based crops

10. <u>Potential industry benefits realised for follow-on project?</u>

a. Healthy seedlings with appropriate pesticide use
b. Water/nutrient loading optimised
c. Plant pest identification and threshold count introduced and effective
d. Crop scouting for in-crop pesticide applications
e. Precise application equipment that is targeted on the crop and to the pest
f. Pesticide alternation and IPM compatibility
g. Pesticide residue compliance
h. Quality product improved or maintained
i. Sustainable production system (future proofing)
j. Not challenge consumer confidence in PC lettuce
k. Voluntary code of practice to adopt new industry standards, etc
l. Community acceptable water management systems, including waste products
m. IPM incorporated pest management strategies
n. IPM and environmentally compatible pesticide use
o. Minimal pesticide use
p. Enhance produce quality
q. Suitable training and assessment in PC spray systems through development of enhanced information for the AgVet farm chemical certificate

Acknowledgements

In my role as Project Leader, I wish to thank the participants (below) for their co-operation and technical input. Their interest in all things greenhouse and hydroponic, and the general spirit of togetherness was most satisfying. I thank them for their friendship and I specially thank them for their contribution to the information included in this report, therefore recognition and appreciation is for their welcome contribution to ensuring a successful project.
I especially thank the 3 commercial hydroponic growers from QLD, NSW & VIC for their frank and open discussions on their current farm practices and full access to their farm production systems and technologies (including full access for potential future new project).

<u>Collaborating Institutions:</u>

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PCA	Saskia Blanch
NSW DPI	Jeremy Badgery-Parker (Gosford NSW)
GOTafe	Leigh Taig & Ross Wade (Goulburn Ovens TAFE, Shepparton VIC)
Rick Donnan P/L	Rick Donnan
HFF	Carl van Loon, President, Hydroponic Farmers Federation, VIC
TAGG	Anthony Brandsema, Tasmanian Association of Greenhouse Growers TAS
WAGGA	Paul Humble, President, West Australian Association of Greenhouse Growers WA
NSW DPI	Len Tesoriero (Pathologist)
PTC+ Ede (Netherlands)	Ben van Onna & Herman Eijkelboom
HAL & AusVeg	Protected Cropping Working Group – all group members
CropHouse Ltd	Elly Nederhoff

Graeme Smith
Project Leader

APPENDIX A (follows attached....)

Basic Greenhouse Crop Protection System

Unit 1 – Greenhouse Spraying – High Volume

Basic Greenhouse Crop Protection Principles

Facilitated by
GRAEME SMITH CONSULTING

WWW.GRAEMESMITHCONSULTING.COM

Basic Greenhouse Crop Protection Principles

Unit 1 – Greenhouse Spraying (High Volume)

n.b. Growers to have completed AGVET Farm Chemicals User Certificate

- Separate equipment for herbicides and pesticides/fungicides (if using 'Roundup', you can rinse over 10 times but will still not cleanout product and will cause plant damage)
- Spray against insects when most active (e.g. thrips most active just after sunrise and 2 hours before sunset, and lowest activity overnight)
- Crop should be wet for at least 2 hours if using systemic chemicals
- Crop should be dry within 4 hours
- Avoid mixing chemicals that are incompatible (leading to phytotoxicity)
  e.g. Powdery Mildew.

Basic Greenhouse Crop Protection Principles

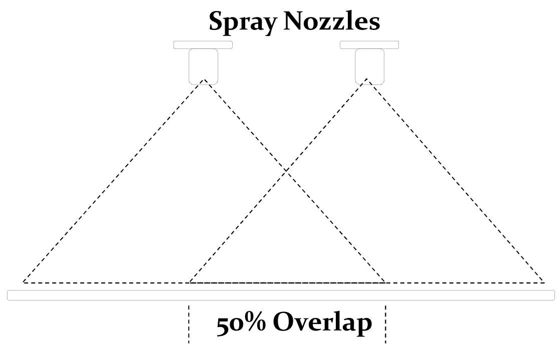
- Spray top of plants only for low mildew infection, remainder down row by row
  (young leaves very sensitive)
- Sugars (mixed various) or pheromones can be added to solution to attract thrips
- Wetting agents can be used to flatten droplets for better coverage and faster dry up (can also be negative?), and to improve contact action for miticides
- Simple wetting agent is $MgSO_4$ (1gm per litre)
- Clean filters after spraying with brush and warm water
- Adjust pH of spray water to ±5 – 6 with Nitric acid (higher pH increases product degradation)
- High volume contact spraying best for insecticides (not fog or LVM), as bigger droplets lead to less evaporation

Basic Greenhouse Crop Protection Principles

Boom Sprays

Spray Nozzles (most important part of any spray system!)

- Correct overlap of the spray widths of adjacent nozzles is essential to obtain a uniform spray distribution across the boom
- The correct overlap is 50%:



Basic Greenhouse Crop Protection Principles


Nozzle Types

- Use 'Flat Spray' nozzles for boom spraying for best uniformity
- Use 'Full Cone' nozzle for hand sprayers and wands

Nozzle Codes

- All TeeJet® nozzles are coded for different performance characteristics
- e.g. XR 8002 VK (or XR 10002 VK)
- XR = Extended Range type (flat spray), suitable for low to high pressures
- 80 = degrees in spray angle (or 110°)
- 02 = Nozzle capacity (output in l/min at *bar)
  e.g. 0.8l/min @ 3bar
  1.0l/min @ 5bar
  1.3l/min @ 8bar
- V = colour code (e.g. yellow)
- K = material (ceramic)

Basic Greenhouse Crop Protection Principles

Boom Pressure (measured at the nozzle!)

- Minimum vertical boom pressure for vine vegetable crops is >5bar (e.g. tomatoes), to ±10bar (for capsicums), to ensure good penetration and cover of both sides of leaf
- Maximum horizontal boom pressure is ±3bar

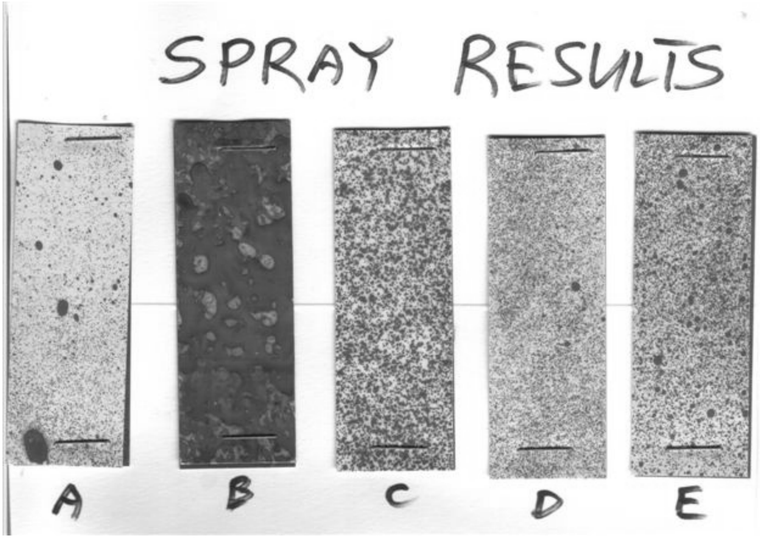
Spray Assessments

- Use 'water sensitive' papers to check effectiveness of spray system
- Place papers low, mid and top of crop and on floor to ensure good cover
- Clip papers to leaves using stapler (front & rear of leaf)

Spray Techniques

- Always start spraying rows from rear to front (to avoid constant exposure to chemicals)
- Every row should be treated in the same direction
- Correct boom speed to be calculated for optimum results

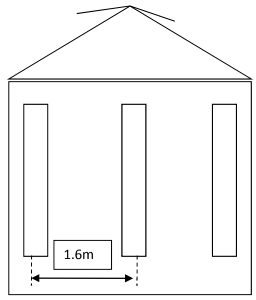
Basic Greenhouse Crop Protection Principles



Basic Greenhouse Crop Protection Principles

<u>Boom (or Walking) Speed</u>

e.g. Area	1,000m2
Amount/area	150litre
Width (path + bed)	1.6m
Nozzle rate (@ 5bar)	1.0l/min
No of nozzles	10



- Speed = $\frac{\text{(nozzle rate x No of nozzles)}}{\text{(Total amount x width)}}$ x 1,000
- Speed = (1.0 * 10 / (150 * 1.6)) * 1,000 = 42m/min

Basic Greenhouse Crop Protection Principles

Total Nozzle Output of a Spray-Boom

e.g.

- Length of spray-boom 2.8m
- Nozzle spacing 0.35m
- Nozzle code XR 8002 VK
- Spray pressure 5bar
- No nozzles 10
- Output of one nozzle @ 5bar = 1l/min
- Total output of spray-boom = 10 * 1 = 10liters/min

Basic Greenhouse Crop Protection Principles

Nozzle Characteristics

- Anti drip
- Shutoff or blank capability
- Flat fan type (for boom)
- Ceramic type (long-life ±1,000 sprays)
- Nozzle angles, 30° forward and 15° up (to cover both sides of leaves)
- Offset adjacent nozzles to avoid clash of 50% overlap
- Replace nozzles when output differs by 10%

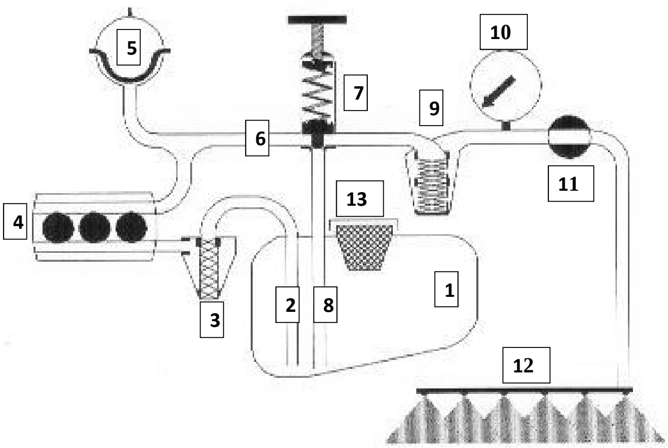
Basic Greenhouse Crop Protection Principles

<u>Emission of pesticides to the environment</u>
May be caused by climatic conditions like:

- high temperatures and low humidity can result in evaporation, thermal air movement and drift, or
- high outside wind speed and vent position can draught spray outside
- Runoff in waste-water from high output dripping from leaves
- Too high a boom spray and spray angle or pressure leading to more spray drift

Basic Greenhouse Crop Protection Principles

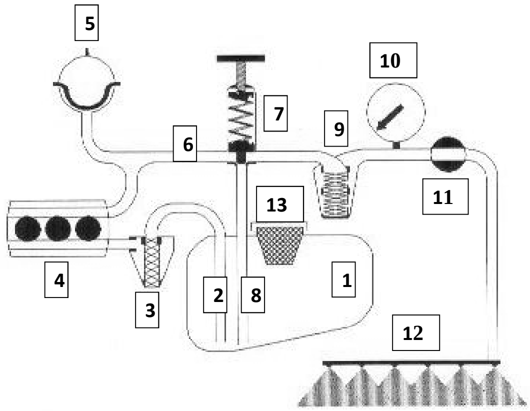
Characteristics of a Good Greenhouse Spray System



Characteristics of a Good Greenhouse Spray System

Component Parts

- **1 - Tank**
- **2 - Suction Line**
- **3 - Suction Filter**
- **4 - Pump**
- **5 - Pressure Chamber**
- **6 - Pressure Line**
- **7 - Pressure Regulator**
- **8 - Return Line**
- **9 - Pressure Filter**
- **10 - Pressure Gauge**
- **11 - Open/Close Valve**
- **12 - Spray Boom/Lance**
- **13 - Tank Fill Filter**



Characteristics of a Good Greenhouse Spray System

<u>General System Notes:</u>

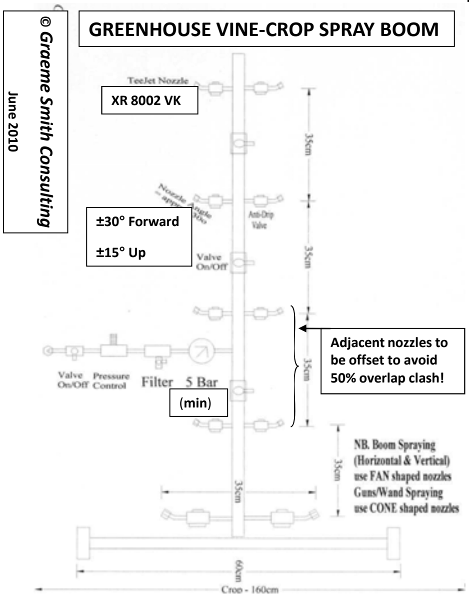
- Tank to be made of chemical resistant material,
- strong enough to hold weight of water,
- round edges to avoid 'dead corners'
- tank outlet at bottom
- fill cover to have a small hole (to avoid vacuum)
- suction line to be reinforced with wire for strength
- pump to be impeller type for higher pressures
- pressure line to withstand max system pressure (e.g. > 10bar?)
- pressure (air) chamber to be set at ±50% of spray pressure (e.g. spray pressure = 5bar, pressure chamber set to 2.5bar)
- pressure regulator type to be 'indirect'
- return line to bottom of tank to direct water flow upwards, and avoid making foam

Characteristics of a Good Greenhouse Spray System

General System Notes:

- return line capacity is min 5% of total tank capacity per minute (e.g. 5% x 200litres = 10litre/min, so if pump capacity is 50l/min, only 40l/min available for spraying)
- pressure gauge to be installed last (just before boom), as we calculate nozzle flow and pressures, not pump!

Characteristics of a Good Greenhouse Spray System



Characteristics of a Good Greenhouse Spray System

Thank You.

Questions?

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