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Advancing integrated pest and disease management (IPM) for vegetable brassicas – final report

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Project name:	Advancing integrated pest and disease management (IPM) for vegetable brassicas
Project number:	04/055
Applicant Group:	Fresh Vegetable Sector Brassica Product Group

A report prepared for
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Contents

1 Project objectives

The vegetable brassica industry initiated a project to update IPM for vegetable brassicas, by revising *Integrated Pest Management for Vegetable Brassicas* (the *IPM Manual*). The project objectives were to:

- update the status of insecticide resistance in diamondback moth (DBM) in New Zealand,
- incorporate newly registered products into the insecticide resistance management rotation strategy, and
- update the disease and other relevant sections in the IPM Manual.

The project team included grower groups from the major vegetable brassica-producing regions, Pukekohe, Gisborne and Manawatu/Horowhenua. Horticulture New Zealand (formerly Vegetable & Potato Growers' Federation Inc. (Vegfed)), the agrichemical industry and other industry partners supported this MAF Sustainable Farming Fund project.

The project work focused on replicated field trials at Pukekohe Research Centre (PRC); regional surveys; field trials in commercial crops at LeaderBrand, Gisborne, field days at Pukekohe; and other field studies in Auckland, Palmerston North, and Canterbury.

2 Brief outline of methodology

All chapters of the IPM Manual were updated. The sections on insects, plant diseases and disorders, insecticide resistance management and the quick reference section required major revision and improvement. Other sections were expanded, and because information on prevention and decision tools are somewhat generic for different crops, particularly for leafy vegetables, information in the recently produced Lettuce IPM Guide was incorporated into this manual where appropriate. Information on new selective pesticides was added. A comprehensive survey of the levels of resistance in DBM to the important chemical groups in the major growing regions was carried out. Growers, key agrichemical companies, and other relevant industry personnel were consulted on positioning of new selective insecticides in the insecticide rotation strategy, and an updated DBM pesticide resistance management rotation strategy was developed. The list of all registered pesticides was updated. The efficacy of a range of insecticides for control of leaf mining flies in Asian brassicas was determined and a field evaluation of the most promising pesticides was undertaken using a number of different types of Asian brassicas. The project reviewed management of vegetable brassica diseases, including bacterial head rots, ringspot and sclerotinia rot. New approaches to disease and pest control were tested in replicated small plot trials. A grower survey was carried out to determine the occurrence and economic importance of diseases and pests of Asian brassicas in New

Zealand. Field trials, undertaken in collaboration with agrichemical companies, were carried out to assess the efficacy of different spray programmes and different fungicide treatment regimes ('new' and currently registered fungicides) for control of downy mildew of vegetable brassicas. New research to investigate the effects of fungicide spray technology and adjuvants for brassica downy mildew control was also carried out. Relevant new information has been and will be communicated to industry by updating the IPM Manual, through articles in the NZ Grower, through direct communication to participating grower groups, and through workshop/seminars for the wider vegetable-growing community.

3 *Objectives*

Objective 1: Planning – to have meetings of stakeholders in July 2004, and team and grower meetings in 2005 and 2006.

Objective 2: Insecticide resistance in DBM − Report to Brassica Product Group of Vegfed on levels of resistance in DBM in three regions to the four major insecticide groups (spinosad, indoxacarb, synthetic pyrethroids and organophosphates). Disseminate results in the NZ Grower and in grower seminars.

Objective 3: Pesticide resistance management strategies − Meet with key stakeholders and update insecticide resistance management strategies, taking into account levels of insecticide resistance in DBM. Rotation strategies would include resistance management for aphids to the selective aphicides Chess and Pirimor. Publish in the updated IPM Manual and NZ Grower.

Objective 4: Control of leaf-mining flies in Asian brassicas. Report to the brassica product group of Vegfed on field trials at Pukekohe Research Centre to compare the efficacy of insecticides registered for use on brassicas (year 1) and novel insecticides (year 2) for control of leaf mining flies on Asian brassicas. One article on each year's progress for the NZ Grower.

Objective 5: Control of insect pests in Asian brassicas − Report to the Brassica Product Group of Vegfed on field trials at Pukekohe Research Centre to test the existing action thresholds for caterpillar and aphid pests on Asian brassicas (year 2) and combine with testing thresholds for leaf mining flies (year 3). Recommend whether they are suitable for incorporating into the updated IPM Manual for vegetable brassicas or if further research is required.

Objective 6: Plant diseases − Report to the Brassica Product Group of Vegfed: (a) Results of field trials at Pukekohe that assessed the efficacy of different spray programmes and treatments using new and presently available fungicides for control of downy mildew and ringspot in vegetable brassica crops; (b) Results of field trials that investigated the effects of fungicide spray technology and adjuvants for brassica downy mildew control. Results published in updated IPM Manual and the NZ Grower. New information on use of resistant cultivars, cultural and chemical control, and biological control of above-ground and soilborne diseases of vegetable brassicas will be incorporated into the updated IPM Manual.

Objective 7: Plant diseases of Asian brassicas − Carry out field surveys to determine the occurrence and economic importance of diseases of Asian brassicas in New Zealand. A written report that will also include recommended methods for control of these diseases will be prepared for the Brassica Product Group of Vegfed on completion of the surveys.

Objective 8: Soilborne diseases − Compile new knowledge on different control strategies for clubroot. Implement new disease control methods for clubroot, based on recent research on effects of biofumigant crops on the disease, and new chemicals for clubroot control.

Objective 9: Tech transfer − Complete grower seminars in Manawatu/Horowhenua, Pukekohe and East Coast to disseminate knowledge gained in field trials and publicise the updated IPM Manual.

Objective 10: IPM manual − Final draft of updated IPM Manual with current information on resistance levels in DBM, updated insecticide rotation strategy, information on pest control in Asian brassicas, and integrated management strategies for diseases of vegetable brassicas, including Asian brassicas.

4 Summary of results

Milestone 1: Planning

- Regular discussions held with agrichemical companies, local growers, and project members contributed to production of a greatly improved Brassica IPM Manual.

Milestone 2: Insecticide resistance in DBM insect pest control

- Resistance surveys were completed for 5 regions for the four key insecticidal modes of action, spinosad (Success™ Naturalyte™), indoxacarb (Steward®), a standard synthetic pyrethroid, (lambda cyhalothrin, Karate® with Zeon) and a standard organo-phosphate (methamidophos, Tamaron®). The areas surveyed were around Pukekohe, Gisborne, Levin, Carterton and Lincoln. All field populations were compared directly with an insecticide-susceptible lab strain of DBM held in quarantine at Mt Albert Research Centre for 14 years. There were still high levels of resistance to the synthetic pyrethroid, but reduced, low or no resistance to methamidophos. There was no resistance to spinosad or indoxacarb, although there was tolerance in two field populations to indoxacarb. This tolerance may be due to natural genetic variation, which is likely to be higher in field populations than in the laboratory population. It appears that resistance in DBM to synthetic pyrethroids is stable but resistance may be decreasing to organo-phosphates.
- The lack of any detected resistance in DBM to spinosad or indoxacarb may be attributed to the adoption of the rotation strategy for these two products by most vegetable brassica growers in the important growing regions.

- Baseline susceptibility surveys were undertaken for Du Pont's new insecticide, Coragen™ (chlorantraniliprole) against DBM from different regions and within the Pukekohe region and compared with the susceptible strain.

Milestone 3: Pesticide resistance management

- The main focus has been on resistance management of DBM. The status of resistance in DBM has been updated (see milestone 2). With this information, we are recommending an update of the DBM insecticide resistance management rotation strategy, which will be published in the IPM manual and in the Grower. This strategy was last updated in 2001 and published in the Grower (December 2001) and on the NZ Plant Protection website,

  www.hortnet.co.nz/publications/nzpps/resistance/index.htm

- The Du Pont product Coragen™ (chlorantraniliprole) is to be registered worldwide next year and in New Zealand it is to be registered for use on vegetable brassicas for control of Lepidopteran species of insect pests. We recommend that this IPM-compatible larvicide is positioned in the early window as an alternative to Btk products and Success™ Naturalyte™.

- Resistance management for aphids has been discussed with relevant industry personnel. The key aphicides are pirimicarb and pymetrozine (Chess®). We recommend that growers consider rotating the use of these two classes of insecticides to ensure that pests are not continually exposed to the same toxins, which could lead to the development of resistance.

- The IPM Manual is being updated to include a pesticide resistance section and resistance management strategies for the important pests and diseases, with references to published strategies, including those on the NZ Plant Protection website (see above).

Milestone 4: Control of leaf-mining flies in Asian brassicas

- The field trials in 2005 to 2007 were funded by FRST and will continue until June 2008. These trials used short rotation brassicas such as Bok Choi.

- Seven insecticides were tested for field control of the leaf mining fly Scaptomyza flava. Acephate, deltamethrin, endosulfan and fipronil gave good control of the flies and reduced damage to an acceptable level. Indoxacarb and spinosad were much less effective at reducing leaf damage. Abamectin, which is not registered for use on brassicas, also gave very good control of the leaf mining fly.

- In the late season trial (autumn), deltamethrin gave best leaf miner control but this option is not suitable as an IPM option where we want to maximise the impacts of natural enemies.

- The seasonal trials showed that the two key larvicides used in rotation to manage DBM (spinosad and indoxacarb) are not effective against leaf miners so other insecticidal options may be required in Asian brassica crops. Abamecton and fipronil gave good leaf miner control and should be considered when trying to conserve natural enemies. Fipronil is toxic to hymenoptera, including the important aphid and caterpillar parasitoids but is considered less harmful to insect predators.

Milestone 5: Control of insect pests in Asian brassicas

- The insecticide field trials for leaf miner fly control were also assessed for control of other insect pests, the damage they caused, and impacts on natural enemies. Trials included testing spinosad, endosulfan, acephate and abamectin in the early trials, and indoxacarb, fipronil, deltamethrin and abamectin in the late season trial.
- The spring and autumn trials had low populations of insects, but the summer trial had reasonably high populations of DBM larvae and predators, particularly hover flies. In the summer trial, there was some evidence of a failure of deltamethrin to control DBM. The data is still to be analysed, but may be due to a non-target negative impact on predators due to its broad-spectrum activity, or possibly resistance in DBM to this product.

Milestone 6: Plant diseases

- Nitrogen and calcium fertiliser applications can affect head rot of broccoli.
- Adjuvant surfactants and nitrogen fertilisers can increase the susceptibility of cauliflower and broccoli heads to head rot.
- Spray technology can have a considerable effect on the efficiency of delivery of fungicide applications to brassicas.

Milestone 7: Plant diseases of Asian brassicas

The questionnaire, sent out to 66 growers of Asian brassicas, revealed that:

- 67% of Asian brassica growers know about the IPM programme for vegetable brassicas,
- 44% of Asian brassica growers use the vegetable brassica IPM programme,
- 94% of growers scout their crops for pests and diseases at least once a week,
- clubroot, downy mildew, and bacterial leaf spot are the three main diseases of Asian brassicas, and clubroot is the hardest disease to control,
- DBM, white butterfly, and aphids are the three main pests of Asian brassicas, and slugs are the hardest pest to control.

Milestone 8: Soilborne diseases

- A first draft of a literature review on ‘Integrated control for clubroot of vegetable brassicas’ (update 2007) was completed and submitted to Crop & Food Research’s editorial system.

Milestone 9: Tech transfer

- 6 scientific papers produced

- 3 conference papers
- 5 poster papers
- 11 reports
- 5 seminars or field days

Milestone 10: IPM manual

- IPM manual submitted to Crop & Food Research editor for publication.

5 Extension activities

March 2005: Graham Walker and Peter Wright met with vegetable brassica growers and Vegfed regional representatives to outline the Advancing IPM for Vegetable Brassicas project; 7 March, Palmerston North.

March 2005: Production of a brochure on the Advancing IPM for Vegetable Brassicas project.

May 2005: Dr Cheah presented an update on integrated management for clubroot at a seminar at the Fruitfed growers' workshop on 18 May 2005, Levin.

March 2006: Presentations by Peter Wright and Graham Walker at grower meetings (Hort NZ Brassica and Leafy crops group), 1 March 2006, Lincoln.

March 2006: Presentations by Peter Wright and Graham Walker on Brassica IPM at Vegetable Technical Conference 2006, 14-16 March 2006, Pukekohe.

February 2007: Graham Walker, Nicholas Martin and Peter Wright updated vegetable brassica growers and Horticulture NZ regional representatives on the Advancing IPM for Vegetable Brassicas project; 19 February 2007, Pukekohe.

6 Publications associated with the project

Cameron PJ, Fletcher JD. 2005. Green peach aphid resistance management strategy. In: Pesticide resistance: prevention & management strategies. Editors N.A Martin, R.M. Beresford, K.C. Harrington. Hastings, NZ. New Zealand Plant Protection Society, 2005: 109-114.

Cameron PJ, Walker GP. 2005. Diamondback moth resistance management and prevention strategy. In: Pesticide resistance: prevention & management strategies. Editors N.A Martin, R.M. Beresford, K.C. Harrington. Hastings, NZ. New Zealand Plant Protection Society, 2005: 49-54.

Cameron PJ, Walker GP. 2005. Tomato fruitworm resistance management and prevention strategy. In: Pesticide resistance: prevention & management strategies 2005. Editors N.A Martin, R.M. Beresford, K.C. Harrington. Hastings, NZ. New Zealand Plant Protection Society, 2005: 55-60.

Cheah, L-H and Falloon, RE. 2006. Integrated disease management for clubroot of vegetable brassicas. Pp. 126-137 in: Ramdane Dris ed. Vegetables: Growing environment and mineral nutrition. WFL Publisher, Fin-00980 Helsinki, Finland.

Cheah, L-H., Gowers S, Marsh AT. 2006. Clubroot control using Brassica break crops. Acta Horticulturae 706: 329-332.

Martin NA. 2005. Thrips insecticide resistance management and prevention strategy. In: Pesticide resistance: prevention & management strategies. Editors N. A Martin, R. M. Beresford, K. C. Harrington. Hastings, NZ. New Zealand Plant Protection Society, 2005: 78-89.

Martin NA, Workman PJ, Hedderley D. 2006: Susceptibility of *Scaptomyza flava* (Diptera: Drosophilidae) to insecticides. New Zealand Plant Protection: 59: 69-74.

Martin NA, Workman PJ. 2006: Control of *Scaptomyza flava* (Diptera: Drosophilidae) in Asian brassicas. Abstract and Talk at the Australian and New Zealand Entomological Societies Conference, 24-27 September 2006, University of Adelaide, South Australia. Abstract page 14.

Walker GP, Martin NA, Griffin B, Falloon R, Teulon, D. 2005. Research on pesticide risk reduction. Poster at: Integrating Initiatives for Pesticide Risk Reduction Workshop, Wellington, 1 December 2005. ERMA.

Walker GP, Clearwater JR, Winkler S, MacDonald F, Wallace AR. 2006: Monitoring of *Thysanoplusia orichalcea* in New Zealand. 5th International Workshop on the management of diamondback moth and other crucifer pests at Beijing, 24-27 October. Conference proceedings: in press.

Wright P. 2006: Survey of growers of Asian brassicas – results and analysis. Crop & Food Research Confidential Report No. 1709. A report prepared for MAF Sustainable Farming Fund and Horticulture NZ.

Wright PJ 2007. Effect of copper and surfactants on head rot of broccoli. (Poster) New Zealand Plant Protection Society 60th Annual Conference, August 2007, Napier.

Wright PJ 2007. Effect of nitrogen and calcium for control of head rot of broccoli. (Poster) New Zealand Plant Protection Society 60th Annual Conference, August 2007, Napier.

Wright PJ 2007. Spray technology for control of foliar diseases of cauliflower. (Poster) 16th Biennial Australasian Plant Pathology Society Conference, September 2007, Adelaide.

Wright PJ 2007. Effects of copper sprays and adjuvants on bacterial soft rot of cauliflower. (Poster) A 16th Biennial Australasian Plant Pathology Society Conference, September 2007, Adelaide.

7 Future plans

In 2007-08, further FRST-funded research will include field trials assessing leaf miner control in Chinese cabbage.

Future work is focused on transferring the IPM tools developed in vegetable brassicas to the forage and seed brassica industries to increase sustainable controls, in particular for DBM, available to the whole brassica industry in New Zealand. A small SFF project is underway, led by a Canterbury vegetable growers group, to assess resistance levels in DBM, and determine whether the recently established white butterfly parasitoid, *Cotesia rubecula*, has established in that region. The project is a precursor to a potentially larger project focusing on the forage and seed industries in the South and North Island where common practice is to use broad-spectrum insecticides, which is disrupting natural controls of key pests.

Also, research funded by FRST is continuing to investigate the non-target impacts of Bt toxins that are now available in brassica plants transformed to express Bt toxins, which have been developed by Dr Mary Christey at Crop & Food Research. The work focuses on assessing the impacts of Bt toxins on the predators and parasitoids of key brassica pests, including non-target pests such as aphids and the polyphagous lepidopteran pests, *Helicoverpa armigera* and *Spodoptera litura*.

8 Financial statement

Period	Date	Amount	Balance	Running total
1 Jul-Sep 05	31/01/2006	$73,756.35	-$73,756.35	
2 Oct-Dec 05	31/01/2006	$73,648.67	-$147,405.02	
3 Jan-Mar 06	18/04/2006	$88,107.60	-$235,512.62	
4 Apr-Jun 06	26/07/2006	$34,712.56	-$270,225.18	
Implementation			**$324,000.00**	
Jul-Sep 05	1/09/2005	$28,640.77	$295,359.23	$28,640.77
Jan-Mar 06	1/04/2006	$46,643.11	$248,716.12	$75,283.88
Apr-Jun 06	1/07/2006	$26,745.69	$221,970.43	$102,029.57
Jul-Oct 06	1/11/2006	$42,135.29	$179,835.14	$144,164.86
Nov-Feb 07	1/03/2007	$25,248.17	$154,586.97	$169,413.03
Mar-Jun 07	1/07/2007	$27,265.50	$127,321.47	$196,678.53
Jul - Sep 07		$15,101.00	$112,220.47	$211,779.53

Appendices

Appendix 1 Brochure on the Advancing IPM for Vegetable Brassicas produced in March 2005

Appendix 2 Wright PJ 2007. Effect of copper and surfactants on head rot of broccoli. (Poster) New Zealand Plant Protection Society 60th Annual Conference, August 2007, Napier.

Appendix 3 Wright PJ 2007. Effects of copper sprays and adjuvants on bacterial soft rot of cauliflower. (Poster) A 16th Biennial Australasian Plant Pathology Society Conference, September 2007, Adelaide.

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Appendix 5 Wright PJ 2007. Spray technology for control of foliar diseases of cauliflower. (Poster) 16th Biennial Australasian Plant Pathology Society Conference, September 2007, Adelaide.

Appendix 6 Walker GP, Martin NA, Griffin B, Falloon R, Teulon, D. 2005. Research on pesticide risk reduction. Poster at: Integrating Initiatives for Pesticide Risk Reduction Workshop, Wellington, 1 December 2005. ERMA.

Appendix 7 Cameron PJ, Fletcher JD. 2005. Green peach aphid resistance management strategy. In: Pesticide Resistance: prevention & management strategies. Editors N.A Martin, R.M. Beresford, K.C. Harrington. Hastings, N.Z. New Zealand Plant Protection Society, 2005: 109-114.

Appendix 8 Cameron PJ, Walker GP. 2005. Diamondback moth resistance management and prevention strategy. In: Pesticide Resistance: prevention & management strategies. Editors N.A Martin, R.M. Beresford, K.C. Harrington. – Hastings, N.Z. New Zealand Plant Protection Society, 2005: 49-54.

Appendix 9 Cameron PJ, Walker GP. 2005. Tomato fruitworm resistance management and prevention strategy. In: Pesticide Resistance: prevention & management strategies 2005. Editors N.A Martin, R.M. Beresford, K.C. Harrington. Hastings, N.Z. New Zealand Plant Protection Society, 2005: 55-60.

Appendix 10 Martin NA. 2005. Thrips insecticide resistance management and prevention strategy. In: Pesticide Resistance: prevention & management strategies. Editors N. A Martin, R. M. Beresford, K. C. Harrington. Hastings, N.Z. New Zealand Plant Protection Society, 2005: 78-89.

Appendix 11 Martin NA, Workman PJ, Hedderley D. 2006: Susceptibility of Scaptomyza flava *(*Diptera: Drosophilidae*) to insecticides. New Zealand Plant Protection: 59: 69-74.*

Appendix 12 Cheah, L-H., Gowers S, Marsh AT. 2006. Clubroot control using Brassica break crops. Acta Horticulturae 706: 329-332.

Clubroot Control Using Brassica Break Crops

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Keywords: biofumigants, brassica crops, clubroot, isothiocyanates, *Plasmodiophora brassicae*

Abstract

Clubroot of brassicas, caused by *Plasmodiophora brassicae*, is the most serious disease of New Zealand's vegetable brassica crops, reducing marketable yields and sometimes totally destroying crops. We investigated the potential of *Brassica* break crops containing high levels of glucosinolates for use in an integrated clubroot management strategy. Two trials were carried out to compare the efficacy of two species of *Brassica* break crops (*B. rapa* and *B. napus*), and to investigate the optimum time required for break crop residues to decompose and provide clubroot control. Seedlings of *Brassica* break crops were grown to about 70 days, ploughed and rotary-hoed to a depth of 12 cm. The plant material was left to decompose for about 1, 2 or 3 months before cauliflower or broccoli were planted as main crops. In the first trial *B. rapa* reduced the mean clubroot severity score on cauliflower root systems, and increased plant top weights compared to plants from untreated plots or from plots treated with cauliflower residues. *Brassica napus* did not reduce the clubroot score. Gas chromatography analysis showed that *B. rapa* had a higher total isothiocyanates (ITCs) than *B. napus*. *B. rapa* released larger quantities of 4-pentenyl ITC than *B. napus*. In the second trial we found that both 2- or 3-month decomposition treatments reduced clubroot severity compared to the untreated or broccoli residue treatments. The 3-month decomposition treatment gave slightly better disease control than the 2-month treatment. The treatments had little effect on plant top weight.

INTRODUCTION

Clubroot of brassicas, caused by *Plasmodiophora brassicae* Woronin, is the most serious disease in New Zealand's brassica growing areas, reducing marketable yields and sometimes totally destroying crops. The above ground symptoms of the disease include wilting of leaves during hot and dry days. Infected roots become severely distorted to form galls (clubs), which characterise the disease.

Good progress has been made towards controlling clubroot through the use of chemicals (Cheah et al., 1999), disease-resistant cultivars (Falloon et al., 1997), and biological control (Cheah et al., 2001). We have also identified *Brassica* spp. with high levels of glucosinolates (GSLs) as biofumigants that could be used as a component of an integrated disease management strategy for clubroot. Upon tissue disruption, GSLs are hydrolysed by endogenous myrosinase to release isothiocyanates (ITCs), thiocyanates and nitriles. ITCs are highly biocidal to a range of organisms including fungi (Sarwar et al., 1998). In a previous field trial (Cheah et al., 2001) we showed that two species of *Brassica* reduced clubroot severity on root systems of Chinese cabbage plants.

This paper reports the results of two field trials to further evaluate two species of *Brassica* (*B. rapa* and *B. napus*) as biofumigants and the optimum time required for their residues to decompose and provide clubroot control. These two *Brassica* lines were screened and selected for their high levels of GSLs in plant tissues by Crop & Food Research at Lincoln, NZ.

MATERIALS AND METHODS

A field trial was carried out at a commercial grower's property on clubroot-infested soil (pH 6.5). In the first trial (Table 1), seedlings of *B. rapa* L. (turnip) and *B. napus* L. (rape) were transplanted (10 plants/m^2) into field plots and grown for about 70 days. The plants were then ploughed and rotary-hoed to a depth of 12 cm. The plant material was left to decompose for about 4 weeks. Cauliflower (cv. Visto) seedlings were transplanted into the trial plots. Control plants were either left untreated or were treated with cauliflower crop residues, which were taken from the remnants of a commercial cauliflower crop, rotary hoed into the plots and allowed to decompose as described above. Samples of root and stem tissues were taken after they were rotary hoed. The samples were freeze-dried and ground and then analysed for released ITCs by gas chromatography using the method of Warton et al. (2001).

In the second trial (Table 3), seedlings of *B. rapa* (10 plants/m^2) were grown, ploughed and rotary hoed as described above. In this trial the plant materials was left to decompose for 2 and 3 months before broccoli (cv. Legacy) was transplanted as the main crop. All treatments were planned such that the main crops were transplanted at the same time. Irrigation was applied immediately after rotary hoeing at 1 litre/m^2 using a hand-held watering can. A total of 4 irrigations were applied. Control plants were either left untreated or treated with broccoli crop residues.

The trial design was a randomised block with six replications, each consisting of four (first trial) or six treatments (second trial). Each treatment plot consisted of a single row of 20 plants at 1.0 m row spacing. After three month's growth, plants were harvested and top weights were recorded. All roots were lifted and scored for clubroot on a 0-5 scale, where 0 = healthy root systems and 5 = complete clubbing of the tap root.

RESULTS

In the first trial, *Brassica rapa* reduced the clubroot score on cauliflower root systems compared to the untreated control plants or plants treated with cauliflower residues (Table 1) and increased the top weight of the plants, although the increase was not significantly different from that with cauliflower residues. *B. napus* did not reduce the clubroot score. Symptoms of stunting were observed on some of the treated plant seedlings, but they soon recovered.

Total ITCs released by *B. rapa* in this experiment were more than that of the *B. napus* (Table 2). However, there were differences in the ITC spectra of the two biofumigant brassica species. *B. rapa* produced a little secondary-butyl ITC whereas *B. napus* had virtually none, and the reverse was the case with methyl thiobutyl ITC. *B. rapa* produced less 3-butenyl and 2-phenylethyl ITCs than *B. napus*, but the major difference was that larger quantities of 4-pentenyl ITC were released by *B. rapa*.

In the second trial there was a high clubroot score for the untreated control and crop residue treatment plants (Table 3). The 2- or 3-month decomposition treatments with or without irrigation reduced the disease severity on root systems. There was no significant difference in disease severity between plants in the 2- and 3-month treatments but plants in the 3-month decomposition treatment had a slightly lower disease score. Irrigation did not improve clubroot control. No symptoms of stunting were observed on any of the treated plant seedlings.

Table 1. Mean clubroot score on root systems and top weight of cauliflower after soil treatment with *Brassica* spp.

Treatment		Rate (plant/m^2)	Mean clubroot score$^+$	Mean top weight (g/plant)
1.	*B. rapa*	10	0.3	227.7
2.	*B. napus*	10	1.7	170.7
3.	Crop residues	-	1.7	202.3
4.	Untreated	-	1.1	141.3
	LSD (P=0.05)		0.7	65.0

$^+$clubroot score; 0=healthy, 5=complete clubbing on root systems

Table 2. Concentration of isothiocyanates from hydrolysed brassica plant tissues.

	Isothiocyanate concentration (umol/g dry matter)					
Brassica spp.	sec-Butyl	3-Butenyl	4-Pentenyl	Me Thiobutyl	2-Phenylethyl	Total
B. rapa	1.04	1.19	9.13	0	4.33	15.69
B. napus	0.08	3.43	0.87	0.74	6.82	11.94

Table 3. Mean clubroot score on root systems and top weight of broccoli after soil treatment with *B. rapa*.

	Treatment	Mean clubroot score*	Mean top weight *B. rapa* (g/plant)
1.	2 mo decomposition	1.0	503.5
2.	3 mo decomposition	0.5	507.8
3.	2 mo decom + irrigation	1.1	574.6
4.	3 mo decom + irrigation	0.3	582.7
5.	Crop residue control	2.6	520.0
6	Untreated control	2.0	472.2
	LSD (P=0.05)	0.9	144.0

DISCUSSION

The present results support our previous findings (Cheah et al., 2001) that *Brassica* tissues actively suppress *P. brassicae* in the soil. The stunting symptoms on plant seedlings may indicate that 1-month decomposition of crop residues was insufficient time for the tissues to break down completely before transplanting of seedlings. Symptoms did not show on seedlings of the 2- or 3-month decomposition treatments, indicating that these time periods are better than 1-month treatment for decomposition of crop residues.

The mechanism of biofumigant action against clubroot involved is not fully understood. However, ITCs that are present within the tissues of *Brassica* are thought to be involved (Smolinka et al., 1997). Our field trial results showed that *B. rapa* gave better control of clubroot than *B. napus*. ITC analysis showed that the two lines had different ITC spectra and this may play an important role in clubroot suppression. *B. rapa* released more total ITCs and if this difference was significant then there could have been a threshold effect, with the *B. rapa* line releasing enough ITCs to control the disease. However, the major difference between the two lines is the much larger quantity of 4-pentenyl ITC released by *B. rapa* and it is thought more likely that this may be the reason for the difference in clubroot suppression. More experiments should be carried out to study the effect of individual ITCs on the clubroot pathogen. Irrigation immediately after rotary hoeing the break crop to improve release of ITCs and disease control was suggested by Matthiessen and Kirkegaard (2002), but our results did not show any significant differences between irrigation and no irrigation treatments.

There may be several modes of action of disease control operating at the same time. Apart from the release of ITCs the *Brassica* crops may also act as 'bait' or 'catch' crops to stimulate the germination of resting spores of *P. brassicae* and reduce the population of inoculum in the soil (Murakami et al., 2000). The increase of plant materials in the soil may also improve drainage and thus reduce clubroot infection.

Our results showed that *Brassica* spp. with high levels of glucosinolates control clubroot on brassica crops and could be used as a component of an integrated disease management strategy for clubroot.

ACKNOWLEDGEMENTS

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Advancing integrated pest management (IPM) for vegetable brassicas

Vegfed

Sustainable Farming Fund

CROP & FOOD RESEARCH
Mana Kai Rangahau

> A three year project has begun to address important issues for the sustainability of the vegetable Brassica industry.

This project has been partly funded by MAFs Sustainable Farming Fund.

Sustainable Farming Fund

Additional funding to make this project possible was provided by the following:

Vegfed

> **Community Contributors**

CELL TECHNOLOGY LTD CELLTECH THE IDEA'S GROWING

BASF The Chemical Company

Bayer CropScience

Elliott Technologies ltd

Millennium Microbes LTD

Seminis Vegetable Seeds

HORTICENTRE

Fruitfed Supplies

> **Valuable in-kind contributions have been made by:**

Brassica Growers	DuPont	Agrimm
LeaderBrand	Dow	Syngenta

Objectives
of this project

> The success of an IPM program comes from selecting a variety of control techniques

Insecticide resistance in diamondback moth

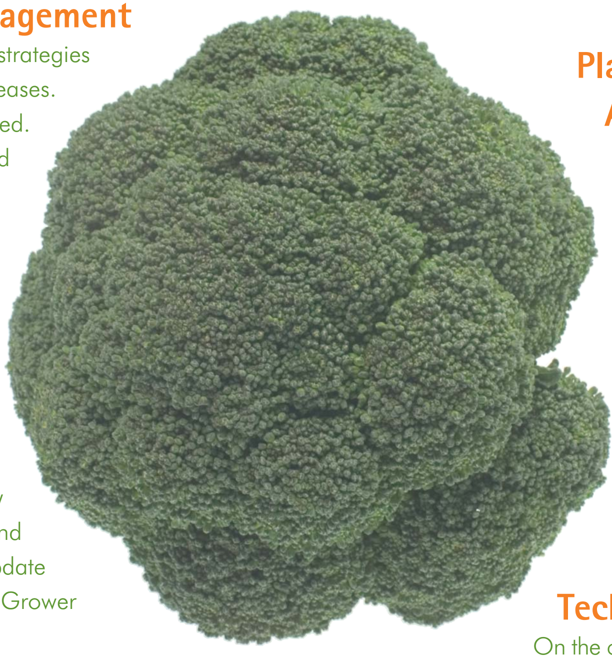
Bioassays will be conducted to assess the levels of insecticide resistance in New Zealand populations of DBM. Results will be published in NZ Grower

Plant diseases

Trialling of various spray programmes for control of fungal diseases. Test the effects of different spray technology and adjuvants.
New information will be incorporated into the updated IPM manual.

Resistance management

The establishment of rotation strategies for all key pests and diseases. Strategies for DBM will be updated. These strategies will be published in the updated IPM manual and in NZ Grower



Plant diseases of Asian brassicas

Field surveys will determine the prevalence and economic importance of diseases on Asian brassicas.

Leaf-mining flies in Asian brassicas

Over the course of this three year project trials will be conducted to compare the efficacy of registered insecticides and novel insecticides. An annual update will be published in NZ Grower

Soil borne diseases

New knowledge on different control strategies for soil borne disease will be compiled and incorporated into the updated IPM manual.

Technology Transfer

On the completion of this project several grower seminars will be conducted to disseminate the knowledge gained, the updated IPM manual will also be available.

Insect pest control for Asian brassicas

Testing of the existing thresholds for caterpillar and aphid pests for their application to Asian brassicas. Testing will also be conducted to set thresholds for leaf mining flies. This will identify if further research is required.

IPM manual

A final draft of the updated Brassica IPM manual will be completed by the end of this project

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Effect of copper and surfactants on head rot of broccoli

P. J. Wright

Introduction

Bacterial soft rot, or head rot broccoli, is a destructive disease found in most vegetable brassica production areas of New Zealand. Head rot is caused by the soft-rotting bacteria *Pseudomonas fluorescens* and *Pseudomonas marginalis*. Both bacteria produce biosurfactants (viscosin) and pectolytic enzymes. The biosurfactants help the bacteria to establish on plant surfaces then the pectolytic enzymes macerate plant tissues. Free water is required for disease initiation, and head rot incidence and severity increase with the presence of prolonged wet weather at head maturity[1].

Some commercial surfactants, added to spray mixes to improve the wetting, spreading, and sticking properties of those agrichemicals, have been reported overseas to increase the susceptibility of some crops to head rot. Copper is used widely worldwide to control bacterial pathogens on many horticultural crops, although there is little quantitative information on copper applications to control head rot of broccoli or cauliflower. It is often applied in combination with a surfactant to improve its adhesion to plant parts. Some local growers apply copper sprays as a 'protectant' against head rot. The purpose of this study was to investigate the effects of copper sprays and commercial surfactant adjuvants on head rot of broccoli.

Method

Broccoli plants, cv. Gaucho, established as cell plants, were planted on 6 April 2006 in sixteen two-row beds at the Crop & Food Research Centre at Pukekohe. The experiment was laid out in randomised blocks with five treatment replications. Plots were 5 m long x 2 beds wide, and treatments were randomly allocated to plots, which were separated by buffer zones of 1.2 m. Each plot contained 40 plants – 10 plants spaced 0.5 m apart along each inside row of the 2 beds. Datum beds were flanked on both sides by a non-sprayed guard bed.

There were eight treatments comprising combinations of four surfactant treatments (no surfactant, Actiwett®, DuWett™, and NuFilm-17® – all at 50 ml/100 L of spray mix), and two copper treatments (no copper and copper oxychloride at 400 g/100 L water at 600 L/ha). Actiwett® is a non-ionic surfactant containing 98 g/L linear alcohol ethoxylate, DuWett™ is a non-ionic surfactant/organosilicone wetter blend, and Rainguard™ is a non-ionic surfactant/pinolene sticker blend. The surfactant/copper treatments were applied to mature broccoli plants on 21 July and 27 July 2006 – 3 days before and 3 days after the heads were sprayed to run-off with bacterial suspensions of *Pm* (ICMP 6039) and *Pm* (ICMP 8127) (both at 10^8 cfu/ml) on 24 July.

Figure 1 Broccoli head showing symptoms of bacterial head rot.

Results

Copper sprays, applied three days before and after inoculation of broccoli heads with soft-rotting bacteria, did not reduce the incidence of head rot. However, surfactant applications significantly ($P < 0.05$) increasing disease incidence, with broccoli heads in the 'no surfactant' treatment having a lower mean incidence of head rot (23%) than broccoli heads in the Actiwett® (37%), DuWett™ (35%), and NuFilm-17® (34%) treatments **(Table 1)**.

Table 1 Percent broccoli heads with head rot symptoms. Back transformed means in brackets.

	No surfactant	Actiwett	DuWett	NuFilm	Mean
No copper	23 (15)	36 (35)	32 (29)	37 (35)	32 (28)
Copper	23 (15)	37 (37)	38 (38)	31 (26)	32 (28)
Mean	23 (15)	37 (36)	35 (33)	34 (31)	

$LSD_{0.05}$ (df = 21) to compare individual means: 12.5
$LSD_{0.05}$ (df = 21) to compare means for copper treatments: 6.2
$LSD_{0.05}$ (df = 21) to compare means for adjuvant treatments: 8.8

Conclusion

The experiment clearly demonstrated that adjuvant surfactants can increase the susceptibility of broccoli heads to head rot. In addition to wetting agents being added to pesticide tank mixes, many pesticides have a surfactant ingredient in the product. To prevent maturing broccoli heads being exposed to adjuvant surfactants, it is recommended that the grower achieves good control of pests and diseases before the head maturing stage. If a pesticide must be used at this time, applications should be made when rain is not forecast.

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Reference

1. Canaday CH, Wyatt JE 1992. Effects of nitrogen fertilisation on bacterial soft rot in two broccoli cultivars, one resistant and one susceptible to the disease. Plant Disease 76(10): 989–991.

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Effects of copper sprays and adjuvants on bacterial soft rot of cauliflower

P. J. Wright

Introduction

Bacterial soft rot, or head rot, of cauliflower and broccoli is a destructive disease found in most vegetable brassica production areas of New Zealand (Figure 1). Head rot is caused by the soft-rotting bacteria *Pseudomonas fluorescens* and *Pseudomonas marginalis*. Both bacteria produce biosurfactants (viscosin) and pectolytic enzymes. The biosurfactants help the bacteria to establish on plant surfaces then the pectolytic enzymes macerate plant tissues. Free water is required for disease initiation. Head rot incidence and severity increase with the presence of prolonged wet weather at head maturity[1].

Some commercial surfactants, added to spray mixes to improve the wetting, spreading, and sticking properties of agrichemicals, have been reported overseas to increase head rot susceptibility. Copper is used worldwide to control bacterial pathogens on many horticultural crops, although there is little quantitative information on copper applications to control head rot of broccoli or cauliflower. However, some growers apply copper sprays in order to control head rot.

The purpose of this study was to investigate the effects of copper sprays and adjuvants on head rot of cauliflower.

Figure1 Cauliflower head rot.

Materials and methods

Cauliflower plants cv. Atlantis established as cell plants, were planted on 18 July 2006. On 22 November, 320 mature heads were harvested and taken back to the laboratory (24˚C). The heads were randomly arranged, face up, in four groups (blocks) containing eight groups (plots) of 10 heads.

There were eight treatments comprising combinations of 4 surfactant treatments (no adjuivant, Actiwett®, DuWett™, and NuFilm-17® – all at 50 ml/100 L of spray mix), and 2 copper treatments (no copper and copper oxychloride at 400 g/100 L water).

The surfactant/copper treatments were applied to the cauliflower heads at a rate of 600 L water/ha using a knapsack sprayer. Twenty-four hours later the heads were sprayed to run-off with bacterial suspension of *Pm* (ICMP 8127) at 10^8 cfu/ml, and then covered with cling film. After 72 h, the cling film was removed and the incidence and severity of head rot were assessed using a head rot score where 0 = no rot; 1 = <5% rot; 2 = 5 – 10% rot; 3 = 10 – 20% rot; 4 = 20 – 50% rot; 5 = >50% rot.

Data was analysed using analysis of variance (ANOVA).

Table 1 Mean head rot score (0 – 5 scale) 72 h after inoculation with *Pm*.

	No Cu	Cu
No adjuvant	2.6	2.4
Actiwett®	3.8	3.5
DuWett™	3.6	3.1
NuFilm-17®	2.4	2.0
LSD ($P < 0.05$)	0.39 (21 df)	

Table 2 Percent cauliflower heads with severe rot (>10% of head rotted) 72 h after inoculation with *Pm*.

	No Cu	Cu
No adjuvant	52.5	47.5
Actiwett®	92.5	80.0
DuWett™	90.0	65.0
NuFilm-17®	32.5	25.0
LSD ($P < 0.05$)	19.23	

Results

Adjuvants significantly (P<0.05) affected mean head rot scores. Cauliflower heads that were sprayed with Actiwett® and DuWett™ had higher disease scores than those not treated with adjuvant or with NuFilm-17® (**Table 1**). Copper applications slightly reduced the mean head rot scores of all adjuvant treatments.

NuFilm-17® significantly ($P < 0.05$) reduced the incidence of severe head rots (>10% of the head rotted) compared to the no adjuvant treatment (**Table 2**). Actiwett® and DuWett™ increased the incidence of severe head rot compared to no adjuvant treatment, and had significantly ($P < 0.05$) higher incidences of severe head rot than NuFilm-17®. Copper applications reduced the incidence of severe head rot scores of all adjuvant treatments.

Discussion

The experiment clearly demonstrated that adjuvant surfactants can increase the susceptibility of cauliflower heads to head rot. The incidence of head rot of cauliflower varies from year to year, and is affected by geographic location, cauliflower cultivar, and crop management practices. If head rot is expected to be problematic, the grower must pay special attention to the selection and use of adjuvants. NuFilm-17® is one adjuvant that does not increase the susceptibility of cauliflower heads to head rot, and it can be added to copper spray applications to help control the disease. Many pesticides have a surfactant ingredient in the product so to prevent cauliflower heads from being exposed to adjuvant surfactants it is recommended that good control of pests and diseases is achieved before the head maturing stage. If a pesticide must be used at this time, applications should be made when rain is not forecast.

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Effects of nitrogen and calcium on head rot of broccoli

P. J. Wright

Introduction

Head rot of broccoli (*Brassica oleracea* var. *italica*), caused by *Pseudomonas marginalis* and *P. fluorescens*, is a major disease in New Zealand. Symptoms of the disease first appear soon after periods of rain, when heads have remained wet for several days. The bacteria are splashed up from the soil to the broccoli head. Enzymes produced by the bacteria enable the pathogen to infect healthy intact plant tissues. Infected areas initially appear water-soaked. Then, in conducive environmental conditions (humid or wet), a brown or black coloured soft decay develops (Figure 1). Head rot downgrades the broccoli head or renders it completely unmarketable. Even small lesions can make a head unsaleable, because, despite cool storage, the soft rot will continue to develop at low temperatures. Currently, there are no effective chemical control measures for bacterial head rot of broccoli.

Overseas studies report that high levels of nitrogen (N) may promote broccoli head rot[1], while low levels of calcium (Ca) may suppress the disease. Plant pathogenic bacteria can usually infect and multiply more rapidly in succulent tissues promoted by abundant N. Low levels of N can cause tougher plant tissues, which are less susceptible to bacterial attack[2]. Calcium can increase the resistance of plant tissue by enhancing the structural integrity of cell walls and membranes, making them more resistant to degradation by pectolytic enzymes produced by pathogens.

The purpose of this study was to determine the effects of N and Ca on head rot of broccoli grown at Pukekohe.

Figure 1 Broccoli head showing symptoms of bacterial head rot.

Method

Broccoli plants, cv. Gaucho, established as cell plants, were planted on 6 April 2006 in sixteen two-row beds at Crop & Food Research, Pukekohe. The experiment was laid out in randomised blocks with five treatment replications. Plots were 5 m long x 2 beds wide, and treatments were randomly allocated to plots, which were separated by buffer zones of 1.2 m. Each plot contained 40 plants – 10 plants spaced 0.5 m apart along each inside row of the 2 beds. Datum beds were flanked on both sides by a guard bed.

Prior to planting, 400 kg 12:10:10 (50 kg N/ha) was applied. Twelve treatments comprising combinations of three N treatments and four Ca treatments were carried out.

The N treatments, as side-dressings of calcium ammonium nitrate (CAN), were carried out 8 weeks after planting. The N treatments were: 'low N' (50 kg N/ha), 'medium N' (100 kg N/ha), and 'high N' (150 kg N/ha). The Ca treatments were: (1) no Ca; (2) pre-plant $CaSO_4$ (gypsum) at 5 t/ha; (3) six foliar applications of Stopit (16% calcium as $CaCl_2$) at 4 L in 1000 L water/ha applied at 7-day intervals from early head formation (13 June); and (4) pre-plant $CaSO_4$ (gypsum) at 5 t/ha and Stopit foliar applications applied as in treatment 3. A bacterial suspension of *Pm* (ICMP 6039) and *Pm* (ICMP 8127) (both at 10^8 cfu/ml) was sprayed on to maturing broccoli heads to the point of runoff using a knapsack sprayer on 24 July. One week after inoculation disease assessments were carried out.

Table 1 Effect of Ca pre-plant applications (gypsum) and Ca foliar applications (Stopit) on head rot incidence. Percent broccoli heads with head rot symptoms. Back transformed means in brackets.

Nitrogen	Transformed mean	Backtransformed (%)
Low	23	16
Medium	24	15
High	29	23
$LSD_{0.05}$ (df = 33)	5.5	

$LSD_{0.05}$ (df = 33) to compare individual means: 6.4

$LSD_{0.05}$ (df = 33) to compare means for Ca treatments: 4.5

Table 2 Effect of N applications (CAN) on head rot incidence. Percent broccoli heads with head rot symptoms.

	No Stopit	Stopit	Mean
No gypsum	26 (19)	27 (20)	26 (19)
Gypsum	29 (23)	20 (11)	24 (17)
Mean	27 (21)	23 (16)	

Results

Data was transformed to arcsine scale to stabilise variance before analysis. High levels of N increased susceptibility of broccoli to head rot (Table 1). Incidence of head rot was significantly (P<0.05) higher in 'high N' heads than in 'low N'. Neither pre-plant Ca (gypsum) or foliar-applied Ca (Stopit) individually reduced head rot, but the combination of both gypsum and Stopit was effective, significantly (P<0.05) reducing head rot incidence (Table 2). There was no significant (P<0.05) N x Ca interaction, although 'low N' together with pre-plant and foliar Ca applications gave the best control of head rot (5% infected heads).

Conclusions

The experiment demonstrated that N and Ca fertiliser applications can affect head rot of broccoli – high levels of N increased the incidence of head rot, Ca applications did not reduce the incidence of head rot but the best control involved low N with both pre-plant and foliar Ca applications. In addition, to optimal use of N and Ca as well as other fertilisers, use of head rot-tolerant cultivars and adoption of cultural practices that modify the crop microclimate and limit disease development are recommended.

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Spray technology for control of foliar diseases in cauliflower

P. J. Wright

Introduction

Ringspot (*Mycosphaerella brassicicola*) and downy mildew (*Peronospora parasitica*) are important foliar diseases of vegetable brassicas. Current control methods for fungal foliar diseases of vegetable brassicas in New Zealand are based on applications of agrichemicals. Integrated pest management (IPM) programs emphasise effective application methods for fungicides and pesticides to ensure good spray coverage of plants in order to minimise the development of pesticide resistance and reduce the number of spray applications while maximising returns to growers. Although it is widely recognised that "good coverage" of fungicide is important, there is little quantitative information regarding the relative effectiveness of spray technologies on fungicides applied to the foliage of vegetable brassicas. Growers use a wide variety of nozzle types, water volumes, and 'spreader-sticker' adjuvants for fungicide spray applications. The purpose of this study was to investigate the effects of nozzle type, water volume and adjuvant on fungicide spray coverage and control of ringspot and downy mildew in cauliflower.

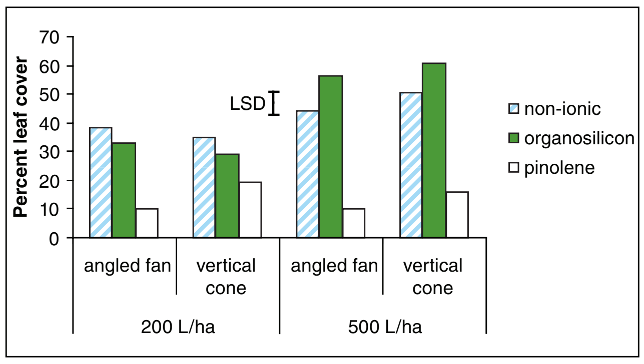

Figure 1 Effect of water rate, nozzle type and adjuvant on spray coverage on cauliflower leaves.

Method

Cauliflower plants cv. Atlantis, established as cell plants, were planted on 18 July 2006 in 2-row beds at Pukekohe. Fertilisers, weeds and pests were managed using local commercial practice. The experiment was laid out in randomised blocks with four treatment replications. Plots were 5 m long x two beds wide, and treatments were randomly allocated to plots, which were separated by buffer zones of 2 m. Each plot contained 40 cauliflower plants – 10 plants spaced 0.5 m apart in each of the four rows. Each datum bed was flanked on both sides by a non-sprayed guard bed.

Twelve spray technology treatments were carried out comprising combinations of:

- two water volumes (200 L/ha and 500 L/ha),
- two nozzle types and two nozzle orientations (vertical conejet nozzles and ceramic fan nozzles, angled at 60° and alternately facing front and rear), and
- three adjuvants (Actiwett® at 50 ml/100 L water, Du-Wett™ at 200 ml/ha, and Rainguard™ at 300 ml/ha).

Actiwett® is a non-ionic surfactant containing 98 g/L linear alcohol ethoxylate, DuWett™ is a non-ionic surfactant/organosilicone wetter blend, and Rainguard™ is a non-ionic surfactant/pinolene sticker blend. Copper oxychloride at a rate of 400 g/100 L of water was added to all spray technology treatments, which were applied at 14-day intervals using a tractor-mounted sprayer from 14 September 2006. Nozzles were spaced 50 cm apart.

On 6 October 2006 a harmless kaolin clay marker (Surround® WP), which is registered for use in crops as a sunscreen anti-transpirant, was added to the treatment sprays at a rate of 6 kg/100 L of tank mix. The kaolin formed a white deposit on the foliage, which allowed accurate determination of the spray coverage on the leaves (**Fig. 1**). Four random, approximately horizontal, outer head leaves from 4 random plants in each plot were photographed using a digital camera. The captured images were subsequently quantified using image analysis software (quant v.1.0.1, Vale et al. 2001) in order to determine mean values for percentage leaf cover of spray deposits (**Fig. 2**).

On 23 November 2006, at early head maturity, the 20 plants from the centre 2 rows in each plot were individually assessed for the incidence of ringspot and downy mildew. The 5 youngest fully expanded leaves were individually assessed for percent leaf area covered with disease lesions. There were no differences in incidence of ringspot between treatments – the levels were very low (0.05–0.08% leaf area covered by ringspot lesions). Downy mildew was not found in any treatments. Data was analysed by analysis of variance (ANOVA).

Figure 2 Cauliflower plant after application of Surround® WP.

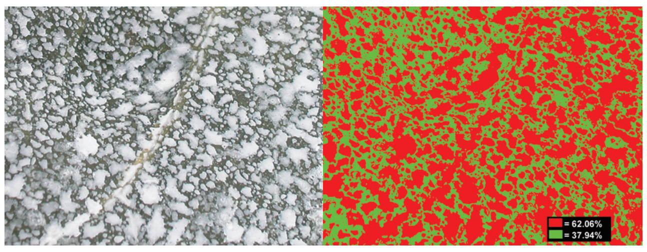

Figure 3 Cauliflower leaf after application of Surround® WP, before and after image analysis.

Results

Incidence of ringspot was very low in this experiment. At early head maturity (23 November 2006), ringspot lesions covered between 0.05 and 0.08% of young fully expanded leaves, and there were no differences between treatments in the incidence of ringspot. Downy mildew was not found in any of the treatments.

The water rate used for spraying and the type of adjuvant used affected the spray coverage of Surround on cauliflower foliage (**Fig. 3**). Rainguard™ gave significantly ($P < 0.05$) poorer spray coverage than Actiwett® and Du-Wett™ for both water rates. Both Actiwett® and DuWett™ provided better spray coverage at 500 L water/ha than at 200 L water/ha. Nozzle types marginally affect kaolin spray coverage. At 200 L water/ha, spray coverage with Actiwett® and Du-Wett™ was better using angled fanjet nozzles, whereas spray coverage was better for Rainguard™ using vertical cone nozzles. At 500 L water/ha, vertical conejet nozzles provided better spray coverage than angled fanjet nozzles.

Conclusion

The study demonstrated that spray technology can have a considerable influence on the efficiency of delivery of fungicide applications on lettuce. Adjuvant and water volume affected fungicide spray coverage on cauliflower leaves. The effect of weathering of the treatments (retention of fungicides on foliage and associated period of effective disease control) could not be determined due to the low levels of ringspot and downy mildew. Further quantitative research needs to be carried out to determine the best spray technology for delivering optimum spray coverage and ensuring the retention of aqueous applications of pesticides on vegetable brassicas.

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Research on pesticide risk reduction

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Introduction

Perceived and real risks from pesticides have led to industry and government support for research to develop sustainable crop protection with minimal pesticide inputs. A key outcome is industry adoption of integrated pest and disease management (IPM) programmes. Research includes plant breeding to improve host plant resistance, assessment of environmental impacts of genetically modified crops, and new plant protection strategies that maximise non-pesticide controls.

Pesticide risk reduction using IPM

Current research and extension programmes, funded largely by MAF Sustainable Farming Fund, Vegfed and industry partners, include developing and implementing IPM for outdoor lettuce, advancing IPM for vegetable brassicas, and developing IPM for Allium crops.

Examples of successful IPM

Combating insecticide resistance was an incentive to adoption of IPM for vegetable brassicas and process tomatoes Insecticide applications have been reduced by >50% and 90% respectively in these crops using IPM.

IPM for vegetable brassicas relies on bio-control of some pests, cost-effective plant scouting systems, customised action thresholds for different varieties, and area-wide insecticide rotations to prevent resistance in diamondback moth.

IPM for process tomatoes uses cost-effective crop monitoring **(Figure 1)**, proven action thresholds, no insecticides for minor pests, and maximising efficacy of tomato fruitworm biocontrol agents.

IPM for greenhouse crops

There is considerable potential to reduce fungicide use in greenhouse tomato crops using new environmental control technologies, and appropriate biological control agents against insect and mite pests.

Challenges for further risk reduction in crops

- Lack of funding to improve IPM programmes
- Unwillingness of industry to support training IPM scouts, mentoring and auditing IPM programmes
- Difficulty with registration of new generation pesticides

Figure 1 **Crop scouting (a cornerstone of IPM) has led to a 90% reduction in insecticide applications in process tomatoes.**

Figure 2 **Potatoes of 'Gladiator' (bottom tubers), a recent powdery scab-resistant cultivar.**

Plant breeding for reducing pesticide requirements

Durable genetic resistance to diseases and pests is a critical component of IPM for most agricultural and horticultural crops. We are developing knowledge of the genetics of resistance to key NZ crop diseases and pests from diverse germplasm sources, and transferring them into appropriate crops using wide-crossing and marker-assisted selection technologies. This research will develop improved commercial cultivars (potatoes (Figure 2), wheat, barley, oats (Figure 3), triticale, peas, brassicas and lettuce) for NZ's food producing industries.

Pesticide reduction in GM crops

We are investigating the environmental impacts of GM crops on non-target pests and beneficial organisms. For example, the deployment of *Bacillus thuringiensis* (Bt) transgenic potatoes and brassicas provides prospects for widespread control of lepidopteran pests in these crops without the use of broad-spectrum insecticides.

Pesticide risk reduction is achieved by:

- Maximising non-pesticide controls, e.g. resistant cultivars, cultural and biological controls
- Minimising use of broad-spectrum pesticides
- Developing crop monitoring and applying action thresholds
- Choosing selective pesticides which maximise activity of natural enemies (Figure 4)
- Incorporating pesticide resistance management strategies
- Safe and effective applications of pesticides (Growsafe-accreditation).

Figure 3 **Susceptible (Awapuni) and resistant (Stampede) oat cultivars to crown rust infection in the Manawatu**

Figure 4 **Parasitoid about to lay an egg into a larva of tomato fruitworm**

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PESTICIDE RESISTANCE:
Prevention and Management Strategies 2005

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Green peach aphid resistance management strategy
(revised October 2004)

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Reason for strategy and update
Green peach aphid, *Myzus persicae*, is capable of becoming resistant to a wide range of insecticide groups. Pest management strategies aimed at preventing or minimising resistance will help maintain control and conserve the effectiveness of existing products. This is an update of an earlier resistance management strategy (Cameron 1996).

Background
Green peach aphid is a polyphagous species that is most important because of its ability to transmit viruses, and may be regarded as the most important vector of aphid-borne viruses. Green peach aphid can overwinter as eggs on its primary woody host, usually peach, or reproduce asexually year-round on a large range of secondary hosts, including potatoes, tomatoes, brassicas, beets, cereals, pasture clovers, peas, roses or weeds, such as docks, sow thistle and capeweed. Viruses transmitted by green peach aphid include alfalfa mosaic, potato leaf roll, tomato yellow top, beet western yellows, cucumber mosaic, lettuce mosaic, potato virus Y, watermelon mosaic virus 2 and zucchini yellow mosaic. Green peach aphid may transmit infection from weed reservoirs harbouring viruses. In addition to the listed hosts, winged green peach aphids have also been found associated with redroot, oxtongue, camomile, chickweed, cleavers, hairy buttercup and scrambling speedwell.

Direct feeding damage by low numbers of green peach aphid causes little damage to plants, although low numbers of aphids can spread unacceptable amounts of plant viruses. In the absence of virus reservoirs, greater green peach aphid populations can be tolerated.

Green peach aphid is distributed worldwide, and several resistant strains have been identified using molecular techniques. A form with a chromosomal translocation is widespread in glasshouses and has been shown to have very high levels of resistance (Blackman & Devonshire 1978).

Products with label claims for green peach aphid control in New Zealand

Table 1: Products with label claims for *Myzus persicae*, green peach aphid (GPA), in New Zealand (October 2002). For a summary of the details of the claims for each crop see Table 2.

Pesticide category	IRAC chemical group	Pesticide common and (product) names
Parasites		*Aphidius colmani* (Aphidius, Aphipar)
Predators		*Aphidoletes aphidimyza* (Aphidoletes)
Mineral oil		mineral oil (BP Crop oil, DC-Tron, Sunspray)
Carbamates	1A	methomyl (Lannate)
		pirimicarb (Pirimor)
Organo-phosphate	1B	acephate (Lancer, Orthene)
		acephate and triforine (Saprene)
		azinphosmethyl (Azinphosmethyl)
		chlorpyrifos (Chlorpyriphos, Jolyn chlor-P, Lorsban, Pychlorex, Spectrum)
		diazinon (Basudin, Dew, Diazinon, Diazinyl, Gesapon)
		dichlorvos (Nuvos)
		dimethoate (Dimezyl, Perfekthion, Rogor)
		maldison (Malathion, Yates Maldison)
		methamidophos (Metafort, Monitor,
		parathion-methyl (Folidol)
		terbufos (Counter)
		thimet (Ground Zero, Phorate, Thimet)
Organophosphates +	1B/3	pirimiphos-methyl + permethrin (Attack) mixture
Cyclodiene	2A	endosulfan (Flavylan, Thiodan)
Pyrethroids	3	alpha-cypermethrin (Bestseller, Dominex, Fastac)
		Bifenthrin (Talstar)
		Deltamethrin (Decis Forte, Deltaphar)
		taufluvalinate (Mavrik, Supershield,
Pyrethrins	3	Pyrethrum (Garlic & Pyrethrum)
Chloronicotinyl	4A	imidacloprid (Confidor 5GR, Gaucho)
Pyridine azomethrine Feeding blocker	9B	pymetrozine (Chess)

Current status of green peach aphid resistance in New Zealand

In New Zealand, insecticide resistance was considered responsible for failures to control green peach aphid in field trials in potatoes (Fellowes & Ferguson 1974). Insecticide resistance was confirmed with bioassays (Cameron & Walker1988). Resistance in greenhouse populations has also been demonstrated (Baker 1978). These studies record resistance to acephate, deltamethrin, demeton-s-methyl, dichlorvos, dimethoate, lindane, maldison, methomyl, mevinphos, naled, parathion methyl and pirimicarb. In the Pukekohe area, growers have reported the failure of demeton-s-methyl to control green peach aphid.

Insecticide resistance by green peach aphid is widespread in Europe, Japan, North America, and Australia. There are records of resistance to organophosphates, organochlorines, carbamates and synthetic pyrethroids, but methamidophos, pirimicarb and methomyl have retained their effectiveness in several regions.

Resistance management and prevention strategy
The general strategy is to reduce the need for control of green peach aphid by reducing virus sources and aphid reservoirs. Selection pressure on aphids in crops can then be reduced by applying insecticides only when necessary to reduce feeding damage.

- Maximise virus control by standard management practices:
    - use virus-free seed (e.g. from pathogen testing schemes) or virus-free transplants
    - remove infected plants within a crop
    - eliminate weed sources that may harbour viruses
    - remove volunteer crop plants
    - use virus-resistant cultivars
    - use screens to prevent entry of aphids to greenhouses
- Remove alternative host plants for green peach aphid, e.g. solanums, brassicas and ornamentals, to create virus-free zones.
- Maximise biological control (especially in greenhouses) by using parasitoids, predators or fungal pathogens of aphids.
- Monitor plants to ensure insecticides are applied only when necessary.
- Choose insecticides based on knowledge of insecticide resistance patterns, where this is available. Resistance to demeton-s-methyl has been identified in Pukekohe.
- Use the correct label rates and application procedures.
- Alternate between insecticide groups.
- If control failures are suspected, treat crops with an insecticide from a different chemical group.

Table 2: Products with label claims for *Myzus persicae*, green peach aphid (GPA), in New Zealand (October 2002). Not all products listed for each pesticide may have a label claim for all crops indicated. Pesticide category and IRAC chemical group are in bold. Product names are in Table 1.

	Type of label claim for each crop[1]											
Pesticide common names	**beans**	**lettuce**	**peas**	**potatoes**	**tomatoes**	**vegetable and forage brassicas**	**vegetable crops**	**stone fruit**	**strawberries**	**tamarillo**	**fruit crops**	**ornamentals/ flowers**
Parasites												
• *Aphidius colemani*							A in GH					A in GH
Predators												
• *Aphidoletes aphidimyza*							A in GH					A in GH
Mineral oil												
• mineral oil							A	A				
Carbamates 1A												
• methomyl	GPA	GPA			GPA	GPA in VB			A			GPA
• pirimicarb	GPA	GPA	GPA	GPA	GPA	GPA		GPA				
Organo-phosphate 1B												
• acephate		A		A		GPA in VB				A		A
• acephate and triforine												A
• azinphosmethyl								A				
• chlorpyrifos						A	A in squash	A				A
• diazinon	A	A			A	A in VB	A in onions	A	A	A	A in CIT	A
• dichlorvos						A	A		A	A		A
• dimethoate			A	A		CA in VB,A in FB			A in BF			
• maldison						A	A	A				A
• methamidophos	A			A								

Pesticide common names	Type of label claim for each crop[1]										
	beans	lettuce	peas	potatoes	tomatoes	vegetable and forage brassicas	vegetable crops	stone fruit	strawberries	tamarillo	fruit crops	ornamentals/ flowers
• terbufos						A in FB						
• thimet				A	A	A	A in CCB					A
Organo-phosphates/pyrethroids 1B/3												
• pirimiphos-methyl + permethrin (Attack) mixture					A in GH	A in VB	A in GH CCB					A
Cyclodiene 2A												
• endosulfan				A	A	A in VB			A			A
Pyrethroid 3												
• alpha-cypermethrin					A			GPA				
• Bifenthrin					A		A in CCB					A
• Deltamethrin							A in squash					
• taufluvalinate					GPA		GPA	GPA				A
Pyrethrins 3												
• pyrethrum							A				A	A
Chloronicotinyl 4A												
• imidacloprid (Confidor 5GR)							A in TSP					A in TSP
• imidacloprid (Gaucho)				A		A in FB	A in squash					
Feeding blocker 9B												
• pymetrozine								GPA				

[1]A=aphids, GPA=green peach aphid (*Myzus persicae*), CA=cabbage aphid, VB=vegetable brassicas, FB=forage brassicas, BF=berry fruit, CCB=cucurbits, GH=greenhouses, TSP=transplants, CIT=citrus.

NOTE: not all products have label claims for control of green peach aphid in all crops listed in a crop grouping.

Research strategy

The distribution of resistance among the major cropping areas should be assessed regularly.

Implementation

Growers should implement virus control strategies.

Insecticides registered for use against green peach aphid should carry the following label statement:

IMPORTANT - RESISTANCE MANAGEMENT
Resistance to this pesticide may develop from excessive use. To minimise this risk use strictly in accordance with label instructions. Avoid using this insecticide exclusively all season and avoid unnecessary spraying. Maintain good cultural practices.

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