THE NEW ZEALAND COMMITTEE ON PESTICIDE RESISTANCE 1989 SUMMARY

R. W. PRINCE* (Chairman)
M. S. MOORE* (Convenor Fungicides Task Group)
C. H. WEARING (Convenor Insecticides Task Group)

*AGCARM, P.O. Box 27-283, Wellington
Entomology Division, DSIR, Auckland

SUMMARY

The New Zealand Committee on Pesticide Resistance (NZCPR) has approved a further four resistance management strategies in addition to the dicarboximide and phenylamide resistance management strategies published in 1988. Resistance management strategies are presented for miticides and leafroller insecticides, covering differing groups of products, and for fungicides belonging to the Benzimidazole, and Demethylation Inhibitor (DMI) Groups.

INTRODUCTION

In accordance with NZCPR policy as reported in the 40th Annual Conference of the Weed and Pest Control Society (Elliott *et al* 1987), four further strategies are presented for publication in this Proceedings of the NZ Weed & Pest Control Conference:—

Miticide (Spider mite) Resistance Management Strategy for Spider Mites.
Leafroller Insecticide Resistance Management Strategy.
Benzimidazole Resistance Management Strategy.
Demethylation Inhibitor (DMI) Resistance Management Strategy.

The aim of the New Zealand Committee on Pesticide Resistance is to develop uniform strategies for the management of pesticide resistance in New Zealand for guidance to all those working in the industry.

TASK GROUPS

Insecticide Task Group

With the completion of the two resistance management strategies in this paper the group will now address resistance management strategies for aphids (especially *Myzus persicae*), greenhouse whitefly (*Trialeurodes vaporariorum*) and diamondback moth (*Plutella xylostella*). Consideration will also be given to developing strategies for other pests such as mealy bug and scale insects.

Fungicide Task Group

Having previously reported the Dicarboximide and Phenylamide Resistance Management Strategies (Elliott *et al* 1988) and the Benzimidazole and Demethylation Inhibitor (DMI) Fungicide Resistance Management Strategies in this Proceedings the Fungicide Task Group have now completed the resistance management strategies requested by the NZCPR.

MITICIDE RESISTANCE MANAGEMENT STRATEGY FOR SPIDER MITES

Research indicates that problems associated with the appearance of spider mite strains resistant to specific miticides can be managed by appropriate strategies and the products conserved for ongoing effective use.

1. Products

Products registered for control of spider mites can be divided into three broad groups; mineral oils, insecticides (mainly organophosphates) and specific miticides.

Proc. 42nd N.Z. Weed and Pest Control Conf.

COMMON NAME (TRADE NAME)						
	organotin	ovicide	organochlorines and relatives	mineral oil	pyrethroid	others
azocyclotin (Peropal)	ERM, TSM					
fenbutatin oxide (Torque)	ERM, TSM					
clofentezine (Apollo)	ERM, TSM					
hexythiazox (Nissorun)	ERM, TSM					
dicofol (Kelthane 35)	ERM, TSM					
dienochlor (Pentac Aquaflo)						
brmopropylate (Neoron 500)						
Mineral oil (Sunspray)						
Mineral oil (DC-Tron)						
fluvalinate (Mavrik Aquaflo)						
propargite (Omite)						

¹ Registration may not cover all berryfruit crops. ERM = European red mite, TSM = twospotted mite, CRM = citrus red mite.

Many products previously registered are now no longer effective. Those currently available in New Zealand which have label claims for miticidal activity are listed below.

2. Current Situation

2.1 ERM resistance to the organotin miticides, azocyclotin¹ and cyhexatin² has developed at some locations in New Zealand. Cross-resistance to fenbutatin oxide has also probably developed.

2.1 ERM and TSM resistance to propargite³ has also developed at some locations.

2.3 ERM resistance to dicofol⁴ has probably developed at some locations.

2.4 While resistance to specific miticides is not widespread in New Zealand at present, excessive applications (more than 3 application per crop, per 12 month period) of miticides could lead to resistant populations becoming more prevalent.

2.5 Resistance to the ovicides (clofentezine, hexythiazox) has not yet been detected in New Zealand, (ovicide resistant TSM occur in Australia⁵ and Spain⁶). Cross-resistance between clofentezine and hexythiazox has been established.⁷

2.6 Resistance to bromopropylate, dinoclor, fluvalinate and mineral oils has not yet been detected in New Zealand.

2.7 Citrus red mite resistance to miticides has not been confirmed in New Zealand, although this has occurred overseas.⁷

2.8 No other miticides are likely to be available in the near future with acceptable international residue tolerance levels.

3. General Strategy

Guidelines to reduce the risk of miticide resistance include:

3.1 Adopt or continue use of integrated mite control programmes using predators.

3.2 Avoid excessive repeated applications of miticides.

i. Ovicides (clofentezine, hexythiazox) — DO NOT make more than ONE ovicide application per crop, per 12 month period.

ii. Other miticides — DO NOT make more than 3 applications per crop, per 12 month period.

3.3 If more than TWO applications are required, use miticides from different chemical groups, including oils where appropriate.

3.4 Ensure that miticide applications are correctly timed and that spray coverage is thorough including the undersides of leaves.

NOTE: CONTROL FAILURE DOES NOT ALWAYS IMPLY RESISTANCE.

4. Implementation

The following recommendations are made:

4.1 Miticide labels should carry the following statement.

IMPORTANT — RESISTANCE MANAGEMENT

Intensive use of miticides could result in the development of resistant strains of spider mites. To minimise this risk, use products strictly in accordance with label instructions.

4.2 This resistance management strategy should be included:

i. In industry-wide spray programmes for export horticultural crops.

ii. On product labels for all miticides.

5. Crop Recommendations

The following options are available for the design of spray programmes.

NOTE: ALL PRODUCTS LISTED MAY NOT BE SUITABLE FOR CROPS BEING EXPORTED TO CERTAIN MARKETS. CHECK WITH YOUR EXPORT AGENCY BEFORE APPLYING ANY PESTICIDE ON EXPORT CROPS. OBSERVE WITHHOLDING PERIODS.

(a) Pipfruit: apples, pears, nashi

An integrated control programme is available for apples using *Typhlodromus pyri* and *Phytoseiulus persimilis*.

*Late dormant — mineral oil for ERM eggs

***Greentip**

EITHER: clofentezine

OR: hexythiazox

AND/OR: mineral oil

***mid-November**

EITHER: clofentezine

OR: hexythiazox

NOTE: DO NOT apply both greentip and mid-November ovicide applications.

***early-December**

EITHER: azocyclotin or fenbutatin oxide

OR: propargite (not pears or nashi)

OR: dicofol

NOTE: Follow recommendations for correct timing of applications for ERM control.

***early-January onwards**

EITHER: azocyclotin or fenbutatin oxide

OR: propargite (not pears or nashi)

OR: dicofol

NOTE: Whenever possible, use a product from a different chemical group to that used in December.

NOTE: All purpose spraying oil can be used throughout the summer at 1% except on russet-prone varieties.

(b) Summerfruit (Stonefruit)

As for pipfruit, except for the following:

ADD, carbophenothion (Trithion 48-E) applied at 50% ERM egg hatch but no later than 20th October (apricots, Central Otago only).

NOTE: All purpose spraying oil can be used throughout the summer at 1% except on russet-prone varieties.

(c) Strawberry***Runner beds:** introduce *Phytoseiulus persimilis*.*** Production beds:** introduce *P. persimilis*.

If predators not present in adequate numbers apply miticides according to label instructions.

EITHER: dicofol

OR: propargite

OR: clofentezine

Ensure thorough coverage and avoid excessive repeated applications (no more than 3 sprays per crop, per 12 month period).

(d) Other berryfruit

CHECK LABELS as not all products are registered for all crops.

EITHER: azocyclotin

OR: bromopropylate

OR: clofentezine

OR: propargite.

Ensure thorough coverage and avoid excessive repeated applications (no more than 3 sprays per crop, per 12 month period).

(e) OrnamentalsAn integrated control programme is available for some flower crops using *Phytoseiulus persimilis*.

EITHER: dienochlor

OR: fluvalinate

Ensure thorough coverage and avoid excessive repeated applications (no more than 3 sprays per crop, per 12 month periods).

(f) Glasshouse vegetable crops

An integrated resistance control programme is available for some vegetable crops using *Phytoseiulus persimilis*.
dicofol

Ensure thorough coverage and avoid excessive repeated applications (no more than 3 sprays per crop, per 12 month period).

REFERENCES

1. Bowie, M.H., Chapman, R.B. and Walker, J.T.S., 1988. Monitoring azocyclotin and propargite resistance in European red mite. *Proc. 41st N.Z. Weed and Pest Control Conf.*: 189-192.
2. Chapman, R.B., Penman, D.R. and Walker, J.T.S., 1987. European red mite resistance to organotin miticides in Hawke's Bay apple orchards. *Proc. 40th N.Z. Weed and Pest Control. Conf.*: 94-98.
3. Chapman, R.B. and Penman, D.R., 1984. Resistance to propargite by European red mite and two-spotted mite. *N.Z. J. Agri. Res.* 27: 103-105.
4. Collyer, E. and van Geldermalsen, M., 1975. Integrated control of apple pests in New Zealand. 1. Outline of experiment and general results. *N.Z. J. Zoo.* 2: 101-134.
5. Edge, V.E., Rophail, J. and James, D.G., 1987. Acaricide resistance in twospotted mite, *Tetranychus urticae* in Australian horticultural crops. In: Thwaite, W.G. (Ed). *Proc. Symp. Mite Control in Hort. Crops*, Orange, N.S.W., Australia: 87-91.
6. Personal Communication, Ehrke, B., 1988. Schering AG, Agrochemical Division, Berlin.
7. Cranham, J.E. and Helle, W., 1985. Pesticide resistance in Tetranychidae. In: Hell, W. and Sabelis, M.W. (Eds). *World Crop Pests — Spider mites: Their Biology, Natural Enemies and Control*, Volume 1B: Elsevier (Oxford).

LEAFROLLER INSECTICIDE RESISTANCE MANAGEMENT STRATEGY

Leafrollers are capable of becoming resistant to insecticides. Management strategies aimed at reducing or preventing resistance will help conserve existing products for ongoing use.

1. Products

Products registered for control of leafrollers fall into four main groups. The list below shows products recommended for application on the indicated crops.

- 1.1 Biological Insecticides
Bacillus thuringiensis — kiwifruit, berryfruit, subtropicals.
- 1.2 Carbamates
carbaryl - pipfruit, stonefruit, berryfruit, subtropicals.
methomyl - berryfruit, grapes.
- 1.3 Organophosphates

1. acephate	citrus, subtropicals
2. azinphos-methyl	pipfruit, stonefruit, berryfruit, kiwifruit
3. clorpyrifos	pipfruit, stonefruit, kiwifruit, citrus, grapes, subtropicals
4. diazinon	kiwifruit, grapes, subtropicals
5. dichlorvos	berryfruit, grapes
6. parathion-methyl	pipfruit, stonefruit, berryfruit
7. phosmet	kiwifruit, grapes, stonefruit, subtropicals
- 1.4 Pyrethroids/Organophosphates
permethrin/pirimiphos-methyl - kiwifruit

All products listed may not be suitable for crops being exported to certain markets. Check with your export agency before applying any pesticide on export crops. Observe withholding periods.

2. Leafroller species

2.1 Leafrollers (Lepidoptera: Tortricidae) with primary pest status in New Zealand include the following species:

Common Name	Species	Distribution
Lightbrown apple moth	<i>Epiphyas postvittana</i>	Throughout N.Z.
Greenheaded leafroller	<i>Planotortrix excessana</i>	Throughout N.Z.
	<i>P. octo</i>	Throughout N.Z.
Brownheaded leafroller	<i>Ctenopseustis obliquana</i>	Throughout N.Z.
	<i>C. herana</i>	South Island
Lyre moth	<i>Cnephasia jactatana</i>	Throughout N.Z.

2.2 Most leafrollers are present on a wide range of plants other than those being grown as crops.

3. Current Situation

3.1 Leafrollers are pests of a wide variety of horticultural crops, and are generally effectively controlled by insecticides. However, only a narrow range of products meet the crop residue tolerances in overseas markets, and this situation is not likely to change in the near future. This increases the risk of resistance and the potential economic impact should it occur.

3.2 Overseas leafroller species have developed resistance to organochlorines (2), carbamates (1) and organophosphates (4).

3.3 Due to the extensive and regular use of insecticides in New Zealand, the potential exists for leafrollers to develop resistance. An example of resistance in the lightbrown apple moth is known from the Nelson district, where an azinphos-methyl resistant strain is confined in distribution to a few orchards. This species had earlier developed DDD resistance. (3).

3.4 Resistance has not been recorded in any other NZ leafrollers.

3.5 The cost of leafroller resistance to New Zealand could be very significant, and this strategy is designed to reduce selection pressure for resistance as far as possible without jeopardising the quality of fruit.

4. General Strategy

The general strategy is to reduce selection pressure for resistance by accurate spray timing, accurate targeting of applications and rotating the insecticides used in a planned programme. This is combined with management practices for the crop and shelter trees which aim to reduce leafroller numbers and improve insecticide coverage. Details are provided below.

NOTE: CONTROL FAILURE DOES NOT ALWAYS IMPLY RESISTANCE.

4.1 Insecticide Use

- Spray only when essential for control.
- Comply with label rates.
- Use correct application procedures, observing correct tractor speeds and spraying conditions to obtain good insecticide coverage.
- Calibrate sprayers at least once per season.
- Follow spray programme recommendations.
- Use effective spray timing, where possible using insect traps or other means. Learn the life cycle of orchard pests so that insecticides are used to their best advantage.

- g. Confine sprays to the crop area: do not spray shelter or other areas around the orchard unless there is a clearly identified source of pest infestation.
- h. Use a range of insecticides. Do not use one single product all season.

4.2 Crop Management

- a. Carry out adequate pruning and thinning where appropriate, to assist spray penetration and coverage, especially into fruiting clusters (e.g. pipfruit, grapes).
- b. Maintain tree and plant sizes and shapes suitable for good spray coverage.
- c. Control weeds, especially docks, plantains, blackberry, gorse, broom and clover which are hosts of leafrollers.
- d. Mow throughout the year to reduce leafroller population in the ground cover.
- e. Destroy mummified or old fruits during winter pruning.

4.3 Shelter Management

- a. Use non-host shelter species such as Casuarina and Bamboo. Avoid using shelter species which are favoured hosts such as willows and poplars.
- b. Remove nearby gorse, broom, blackberry and other host plants to reduce reservoirs of leafroller populations close to the crop.
- c. Spray shelter only if absolutely essential, such as where shelter is known to be acting as a source of crop infestation.

5. Implementation

5.1 Leafroller insecticide labels should carry the following statement:

IMPORTANT — RESISTANCE MANAGEMENT

Leafroller resistance to this insecticide could 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 control practices.

5.2 This resistance management strategy should be included:

- (i) In industry-wide spray programmes for export horticultural crops.
- (ii) On product labels of all insecticides used for leafroller control.

REFERENCES

1. Asakawa, M., 1975. Insecticide resistance in agricultural insect pests of Japan. *Japan Pesticide Information* 23: 5-8.
2. Glass, E.H., 1957. The occurrence of resistance to TDE (DDD) in the red-banded leafroller. *J. Econ. Ent.* 50: 674-675.
3. Suckling, D.M., Chapman, R.B. and Penman, D.R., 1984. Insecticide resistance in the light brown apple moth, *Epiphyas postvittana* (Walker) (Lepidoptera : Tortricidae) : larval response to azinphosmethyl. *J. Econ. Ent.* 77: 579-582.
4. Vakenti, J.M., Campbell, C.J. and Madsen, H.F., 1984. A strain of fruit tree leafroller, *Archips argyrospilus* (Walker) (Lepidoptera : Tortricidae) tolerant to azinphosmethyl in apple orchards of British Columbia. *Can. Entomol.* 116: 69-73.

BENZIMIDAZOLE RESISTANCE MANAGEMENT STRATEGY

1. Product Perspective

1.1 Benzimidazole fungicides have a common mode of action interfering with cell division and hyphal growth of sensitive fungi.

MBC (bmc) (methyl 1 H-benzimidazol-2-ylcarbamate) is common to the 'MBC' subgroup — benomyl-carbendazim, and thiophanate-methyl, either as the principal active ingredient, or as a breakdown compound formed on mixing with water.

1.2 Benzimidazole products registered/licenced for commercial use on crops and pasture in New Zealand —

Chemical Name	Trade Name	Crops
benomyl	'Benlate'	topfruit, field and vegetable crops, cereals and pasture potato tuber treatment
	'Croppers Potato Seed Dust'	
carbendazim	'Bavistin FL'	
	'Delsene 500DF'	as above
thiophanate-methyl	'Topsin M4A'	as above except for cereals
thiabendazole	'Thibenzole'	pasture
	'Tecto'	potato tuber treatment

1.3 These products are upwardly systemic with a broad range of activity on fungal diseases caused by various ascomycetes, fungi imperfecti and basidiomycetes.

Benzimidazole fungicides were introduced into New Zealand in the late 1960's and they offered systemic, curative fungicidal activity on a number of problem diseases — e.g. *Botrytis* in a range of crops, powdery mildew in cucurbits etc.

Principal uses in New Zealand include:—

Pathogen	Disease	Crops
* <i>Botrytis cinerea</i>	botrytis	beans, berryfruit, grapes
* <i>Botrytis elliptica</i>	blossom rot	tomatoes, onions
<i>Botrytis</i> spp.		ornamentals
* <i>Sphaerotheca fuliginea</i>	powdery mildew	cucurbits
* <i>Erysiphe cichoracearum</i>	powdery mildew	cucurbits
* <i>Monilinia fructicola</i>	brown rot	stonefruit
<i>Monilinia laxa</i>	brown rot	stonefruit
<i>Mycosphaerella brassicicola</i>	ring spot	brassicas
* <i>Mycosphaerella fragariae</i>	leaf spot	strawberries
* <i>Penicillium digitatum</i>	blue mould	citrus
<i>Penicillium italicum</i>		
<i>Pithomyces chartarum</i>	facial eczema	pasture
<i>Podosphaera leucotricha</i>	powdery mildew	apples
* <i>Pseudocercospora herpotrichoides</i>	eyespot	cereals
<i>Rhynchosporium secalis</i>	scald	barley
<i>Sclerotinia</i> spp.	sclerotinia	beans, lettuce, tobacco, tomatoes
<i>Septoria tritici</i>	speckled leaf blotch	wheat
* <i>Venturia inaequalis</i>	black spot	apples
* <i>Venturia pyrina</i>	black spot	pears
Minor Uses		
* <i>Microdochium nivale</i>	fusarium patch	turf
<i>Rhizoctonia</i> spp.	brown patch	turf
* <i>Septoria apiicola</i>	celery leaf spot	celery
* <i>Fusarium avenaceum</i>	carnation stub die-back	carnations
* <i>Penicillium verrucosum</i>	garlic clove rot	garlic

*Diseases for which resistant strains have been identified in New Zealand.

1.4 Resistance frequencies vary considerably depending on the cropping history and benzimidazole use.

1.5 Lack of control and yield loss are common when resistance occurs. Strains resistant to the benzimidazoles are genetically stable and usually of equal fitness to sensitive strains, and persist even after discontinuing benzimidazole use.

1.6 All resistant strains are cross-resistant to other benzimidazole fungicides.

2. Current Situation

2.1 Resistance has not been found in N.Z. or elsewhere to *Pithomyces chartarum*, *Sclerotinia sclerotiorum* and *S. minor* or *Podosphaera leucotricha*.

2.2 Control failure and publicity about the potential for resistance to develop, have effectively reduced or curtailed the use of benzimidazole fungicides over the past 12 years in many disease situations.

2.3 A general resistance strategy was introduced in 1977 which included:

- a. Restriction on new label claims and voluntary removal of some label claims by proprietors.
- b. Recommending use of benzimidazoles in mixtures with non-benzimidazole fungicides.
- c. Limiting the frequency of use to 'critical' periods of a disease cycle.
- d. Recommending the use of alternative products in an alternating programme.
- e. The inclusion of some form of resistance warning statement on labels.

2.4 A range of alternative fungicides have become available and these have often become dominant where benzimidazoles were used intensively in the past.

2.5 Where resistance has developed or threatens to develop against some of the newer alternative products, benzimidazoles are being reconsidered for tactical use in programmes, particularly where benzimidazole resistant strains are not common.

3. General Strategy

3.1 Where resistant strains of the pathogen are known or likely to be common avoid benzimidazole use.

3.2 If resistance frequency is nil or low, use a maximum of 2 applications per crop per 12 month period.

3.3 Confine use to periods when disease risk is high.

3.4 Where practical apply in a mixture with a protectant fungicide.

3.5 Comply with label rates at all times.

3.6 Practise good crop hygiene and cultural control.

4. Recommended Crop Strategies

4.1 Do not apply more than two (2) applications on any crop within a 12 month period, including crops where benzimidazoles may be indicated for the control of two or more pathogens — eg *Sclerotinia* and *Botrytis* in vegetables.

4.2 Do not use against a target pathogen in districts where resistance frequency is known to be high eg, botrytis in grapes for all districts except Gisborne.

4.3 Specific crop/disease recommendations.

Crop	Disease	Recommendations
stonefruit	brown rot	Confine use to the blossom period only.
pipfruit	black spot	Confine use to the period from 2nd cover to preharvest, when infection pressure is high. Apply only in a mixture with protectant fungicides eg captan, mancozeb or metiram
grapes, strawberries, raspberries and brambles, tomatoes and beans	botrytis	Do not exceed one (1) application per season.
cucurbits	powdery mildew	Use in programme with alternative products.
tomatoes, beans and lettuce	sclerotinia	Limit use to early season (blossom to 14 days post blossom on flowering crops).

Cont/d

Crop	Disease	Recommendations
wheat	eyespot	Apply only in second year crop. If control was below expectation use an alternative product in the third year.
wheat	speckled leaf blotch	Comply strictly with recommended timing (last week of August).
barley	scald	Comply with label rates and timing.

5. Implementation

5.1 The following resistance statement is recommended for inclusion on all benzimidazole product labels:—

“Resistance to this fungicide and related benzimidazole (MBC) fungicides has developed from repeated use in some disease situations. In order to help prevent further development of resistance, use strictly in accordance with label instructions”.

5.2 Label recommendations should be modified to incorporate these strategies.

5.3 Recommendations for the use of benzimidazoles to complement resistance strategies for other fungicide groups should be considered.

REFERENCES

1. Beever, R.E. and O'Flaherty, B.F., 1985. Low level benzimidazole resistance in *Botrytis cinerea* in New Zealand. *N.Z. J. Agri. Res.* 28: 289-29.
2. Davidse, L.C., 1982. Benzimidazole compounds: selectivity and resistance. In: Dekker, J. Georgopoulos, S.G. (Eds.), *Fungicide Resistance in Crop Protection*. Wageningen, Pudoc: 60/70.
3. Dekker, J., 1977. Resistance. In: March, R.W. (Ed.) *Systemic Fungicides*. London, Longman pp. 176-197.
4. Gilpatrick, J.D., 1982. Case study 2: *Venturia* of pome fruits and *Monilinia* of stone fruits. In: *Fungicide Resistance in Crop Protection*. Wageningen, Pudoc pp. 195-206.
5. Hartill, W.F.T., 1986. Resistance of plant pathogens to fungicides in New Zealand. *N.Z. J. Exp. Agri.* 4: 239-245.
6. King, A.C., Cromey, M.G., Sanderson, F.R. and Scott, P.R., 1984. Resistance to benomyl in isolates of the eyespot fungus in cereals in Southland. *Proc. 37th N.Z. Weed and Pest Control Conf.*: 290-293.

DEMETHYLATION INHIBITOR (DMI) FUNGICIDE RESISTANCE MANAGEMENT STRATEGY

1. Product Perspective

1.1 Demethylation Inhibitors — DMI's (a sub group of the Ergosterol Biosynthesis Inhibitors — EBI's) are a chemically diverse group of highly effective fungicides, many of which show systemic properties. Despite this diversity they show a common mode of action in disrupting sterol synthesis, primarily at one site. Other EBI's (morpholines and piperidines) have a different mode of action and are therefore not included in this resistance management strategy.

1.2 Those DMI's registered (or which may be registered) in New Zealand include:

DMI Group	Chemical Name	Trade Name
imidazoles	imazalil	'Fungaflor' 'Baytan IM' (+ triadimenol) 'Fungazil' 'Vincit' (+ flutriafol)
	prochloraz	'Sportak' 'Octave'
piperazines	triforine	'Saprol' in 'Saprene';
pyridines	pyrifenoxy	**'Dorado'
pyrimidines	fenarimol	'Rubigan'
triazoles	bitertanol	'Baycor'
	cyproconazole	**'Alto'
	diniconazole	**'Spotless'
	flutriafol	'Impact' 'Vincit' (+ imazalil)
	flusilazol	'Nustar'
	hexaconazole	**'Anvil'
	myclobutanil	'Systhane'
	paclobutrazol	***'Cultar'
	penconazole	'Topas' in 'Topas MZ'
	propiconazole	'Tilt'
	terbuconazole	**'Folicur'
	triadimefon	'Bayleton'
	triadimenol	'Baytan IM' (+ imazalil) 'Cereous'

* Not yet registered

** Registered as a plant growth regulator

1.3 This table lists some of the more common pathogens controlled by one or more of these fungicides.

Pathogen	Disease	Crop
Horticultural crops		
<i>Colletotrichum</i> spp	anthracnose	avocado
<i>Colletotrichum (Glomerella)</i> spp.	leaf spot	ornamentals
<i>Erysiphe cichoracearum</i>	powdery mildew	cucurbits
<i>Fulvia fulva</i>	leaf mould	tomato
<i>Monilinia</i> spp.	brown rot	stonefruit
<i>Mycosphaerella fragariae</i>	leaf spot	strawberry
<i>Podosphaera leucotricha</i>	powdery mildew	apple
<i>Penicillium</i> spp.	blue mould	citrus
<i>Puccinia chrysanthemi</i>	rust	chrysanthemum
<i>Puccinia horiana</i>	white rust	chrysanthemum
<i>Sphaerotheca fuliginea</i>	powdery mildew	cucurbits
<i>Sphaerotheca pannosa</i>	powdery mildew	rose
<i>Ucinula necator</i>	powdery mildew	grape
<i>Venturia</i> spp.	black spot	pipfruit

Cont/d

Pathogen	Disease	Crop
Cereal Crops		
<i>Blumeria graminis</i>	powdery mildew	wheat
<i>Leptosphaeria nodorum</i>	glume blotch	wheat
<i>Mycosphaerella graminicola</i>	speckled leaf blotch	wheat
<i>Pseudocercospora herpotrichoides</i>	eyespot	wheat
<i>Puccinia graminis</i>	stem rust	wheat
<i>Puccinia recondita</i>	leaf rust	wheat
<i>Puccinia striiformis</i>	stripe rust	wheat
<i>Tilletia tritici</i>	bunt	wheat
<i>Ustilago tritici</i>	loose smut	wheat
<i>Bipolaris sorokiniana</i>	spot blotch	barley
<i>Blumeria graminis</i>	powdery mildew	barley
<i>Puccinia hordei</i>	leaf rust	barley
<i>Pyrenophora teres</i>	net blotch	barley
<i>Rhynchosporium secalis</i>	scald	barley
<i>Ustilago hordei</i>	covered smut	barley
<i>Ustilago tritici</i>	loose smut	barley
<i>Puccinia graminis</i>	stem rust	oat, ryegrass seed crop
<i>Puccinia coronata</i>	crown rust	oat, ryegrass seed crop
<i>Ustilago avenae</i>	loose smut	oat
<i>Ustilago hordei</i>	covered smut	oat

2. Current Situation

Available evidence indicates that excessive use may lead to resistance problem. With the DMI fungicides (9). In the laboratory, resistant strains have been readily found in a wide range of species, but in the field resistant strains have been reported for only a few species.

2.1 Horticultural Crops

Resistant strains of *Sphaerotheca fuliginea* on cucurbits have been found in several overseas countries where their presence has been linked with some loss of disease control (11). Recently resistant strains have been found in New Zealand (G.I. Roberston pers. comm. 1989).

In apple, resistant strains of *Venturia inaequalis* have been found in Europe (3, H. Scheinpflug pers. comm., W. Kennel pers. comm.) and in Canada (10). There are, at present, no indications of resistant strains in New Zealand (6).

In California, resistant strains of *Penicillium digitatum* have been reported from citrus packhouses (2).

In grape, some loss of powdery mildew control has been associated with the presence of resistant strains of *Uncinula necator* in Portugal (8) but the evidence from California is, as yet, equivocal (8).

2.2 Cereal Crops

Resistant strains of powdery mildew of barley and wheat have been detected in the field overseas (4, 15). Resistance has involved a gradual shift in sensitivity beyond the range encountered in natural populations, and in some localities has caused a decrease in control.

Strains of *Rhynchosporium secalis* resistant to DMI's have been associated with loss of performance in Europe (FRAC, pers comm.), and a similar situation appears to be developing in New Zealand (13).

Strains of *Pyrenophora teres* resistant to triadimenol have been associated with control failure in New Zealand, the strains apparently being imported on seed from Europe (12).

A report of resistance in *Pseudocercospora herpotrichoides* in New Zealand (7) has not been confirmed (1).

2.3 Cross Resistance

Cross resistance occurs between DMI's although there are differences in relative efficacy; therefore alternating or mixing products within this group are not suitable strategies to avoid resistance development.

3. General Strategy

NB: CONTROL FAILURE DOES NOT NECESSARILY IMPLY RESISTANCE.

- 3.1 Restrict the number of applications per season.
- 3.2 Where practical always apply in a mixture with a non-DMI fungicide.
- 3.3 Confine use to a portion of the crop cycle where disease risk is high and use non-DMI fungicides for the remainder of the season.
- 3.4 Do not use in rescue attempts where disease is prevalent and obvious. DMI's should be used only during periods that favour disease, but while disease incidence is low.
- 3.5 Where DMI's are used to control more than one pathogen in a crop (e.g. *Venturia inaequalis* and *Podosphaera leucotricha* in apple) maximum usage should not exceed that recommended for any individual disease.
- 3.6 Practise crop hygiene and cultural control.
- 3.7 Practise correct spray timing and application.
- 3.8 Comply with label rate at all times.
- 3.9 The following resistance statement is recommended for inclusion in all DMI product labels:

"Resistance to this fungicide and related DMI products could develop in some disease situations from repeated use. To minimise this risk use strictly in accordance with the label instructions".

4 Individual Crop Strategies

4.1 Apple (black spot, powdery mildew), Pear (black spot)

DMI's should not be used alone, but mixed with a protectant fungicide, such as captan, mancozeb, metiram or with dodine. The number of DMI plus protectant applications should not exceed four per season, preferably confined to the period from tight cluster to second cover. In seasons of extreme disease pressure a maximum of six applications in a mixture could be used, but this will increase the risk of resistance.

4.2 Grape (powdery mildew)

Use a maximum of four DMI applications per season, preferably mixed with a protectant fungicide (e.g. sulphur, chlorothalonil). Do not apply before flowering. No more than two DMI's should be applied alone per season.

4.3 Stonefruit (brown rot)

Apply a maximum of three DMI applications, preferably in a mixture, over flowering up to shuck fall. Use non-DMI fungicides at other times. Ensure full coverage of foliage.

4.5 Cereals

Use a maximum of three DMI applications, including seed treatment, per crop, at full recommended label rates. Use of a non-DMI fungicidal seed treatment is encouraged to control bunt, smuts, net and spot blotch and seedling rots/blights. In situations where powdery mildew is expected to be severe, use DMI's in conjunction with alternative products (e.g. morpholines).

5. Implementation

5.1 Label claims should incorporate the above strategies, and labels must be referred to for specific directions.

5.2 Sensitivity monitoring programmes should be applied to the following, at risk priorities, for crop disease/pathogens.

1. Apple — black spot (*Venturia inaequalis*)
2. Cucurbits — powdery mildew (*Sphaerotheca fuliginea*)

3. Stonefruit — brown rot (*Monilinia* spp.)
4. Barley — scald (*Rhynchosporium secalis*)
5. Grape — powdery mildew (*Uncinula necator*)
6. Wheat — stripe rust (*Puccinia striiformis*)
7. Barley — *Drechslera* spp.

REFERENCES

1. Birchmore, R.J., Buckley, E.S., Bowning and S., Russell, P.E., 1987. Sensitivity to prochloraz and carbendazim of New Zealand isolates of *Pseudocercospora* spp. *Aust. Plant Path.* 16: 66-67.
2. Eckert, J.W., 1988. Resistance of *Penicillium digitatum* to imazalil treatments in California packing houses. *ISPP Chemical Control News*. 10: 36-38.
3. Fiaccadori, R., Gielink, A.J. and Dekker, J., 1987. Sensitivity to inhibitors of sterol biosynthesis in isolates of *Venturia inaequalis* from Italian and Dutch orchards. *Netherlands J. Plant Path.* 93: 285-287.
4. Fletcher, J.T., Cooper, S.T. and Prestidge, A.L.H., 1987. The sensitivity of *Erysiphe graminis* f.sp. *tritici* to various fungicides inhibiting sterol biosynthesis. *ISPP Chemical Control News*. 9: 30-32.
5. Hartill, W.F.T., 1986. Resistance of plant pathogens to fungicides in New Zealand. *N.Z.J. Exp. Agri.* 14: 239-245.
6. Hartill, W.F.T. and Wilton, W.J.W., 1987. Future problems with fungicides? *The Orchardist of N.Z.* 60: 385-387.
7. King, A.C., Cole A.L.J. and Sanderson, F.R., 1986. Prochloraz insensitivity in isolates of the cereal eyespot fungus, *Pseudocercospora herpotrichoides*, in New Zealand. *Australasian Plant Pathology* 15: 22-23.
8. Klassen, P., 1987. Powdery mildew can be controlled. *Farm Chemicals* 150 (5): 20-21.
9. Koller, W. and Scheinpflug, H., 1987. Fungal resistance to sterol biosynthesis inhibitors: A new challenge. *Plant Disease* 71: 1066-1074.
10. Lockhart, C.L. and Newberry, R.J., 1988. Apple (*Malus sylvestris* 'McIntosh', 'Cortland') Scab; *Venturia inaequalis*. *Fungicide and Nematicide Tests* 43: 26.
11. O'Brien, R.G., Vawdrey, L.L. and Glass, R.J., 1988. Fungicide resistance in cucurbit powdery mildew (*Sphaerotheca fuliginea*) and its effect on field control. *Aust. J. Exp. Agri.* 28: 417-423.
12. Sheridan, J.E. and Nendick, D.K., 1987. Strains of *Pyrenophora teres* in New Zealand barley crops with reduced sensitivity to ergosterol biosynthesis inhibitor fungicides. *Proc. 40th N.Z. Weed and Pest Control Conf.*: 172-175.
13. Sheridan, J.E. and Nendick, D.K., 1988. Control of *Rhynchosporium* scald of barley by seed and foliar fungicides. *Proc. 41st N.Z. Weed and Pest Control Conf.*: 30-33.
14. Steva, H., Cartolaro, P., Clerjeau, M., Lafon, R. and da Silva, M.T.G., 1988. Une resistance de l'oidium au Portugal. *Phytoma* 402: 49-50.
15. Wolfe, M.S., 1985. Dynamics of the response of the barley mildew to the use of sterol synthesis inhibitors. *EPPO Bulletin* 15: 451-457.

CONCLUSIONS

The Insecticide and Fungicide Task Groups of the NZCPR have issued a further four resistance management strategies in addition to the two published in 1988. The resistance situation is not static locally or internationally and the NZCPR sees a continuing need to periodically review, and update, the strategies as the situation warrants.

While these resistance management strategies have each been developed in isolation, the challenge lies before the NZCPR to ensure these strategies are integrated into effective programmes for growers to utilize in their crop management.

ACKNOWLEDGEMENT

To NZCPR, members and co-opted members of the Task Groups.

REFERENCES

- Elliott, G.S., Wearing, C.H., and Suckling, D.M. 1987. Formation of the New Zealand Committee on Pesticide Resistance. *Proc. 40th N.Z. Weed and Pest Control Conf.*: 84-89.
- Elliott, G.S., Moore, M.S. and Wearing, C.H., 1988. The New Zealand Committee on Pesticide Resistance 1988 Summary. *Proc. 41st N.Z. Weed and Pest Control Conf.*: 288-292.