A review of insecticide use on pastures and forage crops in New Zealand

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Table of Contents

Summary

- Pesticides (insecticides, fungicides and herbicides) have been used widely over pastoral land in New Zealand for the past 60 years to protect pasture and forage crops from pests (insects, fungi, and weeds). Intensification of pastoral land production would not have been possible without pesticides.
- In 2004, approximately 1,278 tonnes of pesticide active ingredient from all pesticide classes was applied over 7,654,734 hectares of pastoral land which averages to 0.17 kg of pesticide active ingredient per hectare, per year.
- In 2004, approximately 79 tonnes of insecticide active ingredient was applied to pastoral land, the majority of which (76 tonnes) was applied to dairy pasture (on average approximately 0.05 kg active ingredient, per hectare, per year).
- A broad variety coleopteran, lepidopteran and hemipteran and other species of native and introduced origin attack the roots, stems, leaves and seeds of pasture and forage crops. Some pests are widespread and persistent, while others are more localized and occur sporadically.
- Insecticides have many distinct advantages over other methods of control for pasture and forage pests, and when used effectively provide good economic returns. However, the longer term availability of many insecticides is uncertain.
- The intensification of New Zealand agriculture has, in part, relied on pesticides to combat pest organisms. In the modern chemical era of synthetic insecticides (1960s onwards) insecticides from a range of chemical classes (organochlorine, organophosphate, carbamate, pyrethroid, benzoyl phenyl urea, neonicotinoid) and microbial insecticides (*Serratia* sp., *Bacillus* sp.) have been used against pasture and forage crop pests.
- In 2010, there were 28 insecticidal active ingredients in over 60 commercial products registered for insect (and nematode) control on pastures and forage crops. The active ingredients are dominated by organophosphates (11), pyrethroids (6), carbamates (5), neonicotinoids (3), benzoyl phenyl urea (1), microbial (1) insecticides.
- Twenty six pest species (or related groups) have registered uses listed on insecticide product labels. The number of active ingredients for each pest species (or group) is: Argentine stem weevil (7), black beetle (3), clover root weevil (1), grass grub (7), Sitona weevil (3), Tasmanian grass grub (3), weevils (unspecified)(3), armyworm (6), clover casebearer (2), corn earworm (7), diamondback moth (8), greasy cutworm (7), porina (5), white butterfly (6), aphids (all species)(13), green vegetable bug (1), wheat bug (3), mirids (1), Australian soldier fly (1), brassica leaf miner (1 combination product), black field cricket (1), thrips (1), springtails (11), redlegged earth mite (1), plant parasitic nematodes (2).
- Reviews of 10 insecticide active ingredients used on pasture and forage crops are currently under way (or due to be reviewed soon). Many of these insecticides (mainly organophosphates) are not listed on Annex 1 of permitted pesticides for the European Community, and many of the same active ingredients are under review by the US EPA. The availability of these active ingredients in the short to medium term (up to 5-7 years) is uncertain.
- Removal of organophosphate and carbamate insecticides could increase the risk of resistance development by some pests to other classes of insecticides.
- The ongoing commercial availability of some older insecticides in New Zealand is in doubt because of low sales volumes, lack of technical support and supply, or regulatory review of registrations. Prospects for the introduction of new insecticide active ingredients appear to be quite limited given the small market size for most products on pasture and forage crops, lack of sufficient data protection for agrichemical companies and other commercial considerations.

1.0 Introduction

1.1 Pastoral land in New Zealand

Pastoral land has been a feature of the New Zealand landscape since European colonization and the introduction of sheep, cattle and other grazing animals. In 2004, pastoral land occupied approximate 10 million hectares of which 1.88 m hectares was dairy pasture (7.0% total land area), 3.84 m hectares intensive sheep and beef (14% total land area), 4.07 m hectares hill and high country sheep and beef (15% total land area), and 0.25 m hectares deer pasture (0.9% total land area). By contrast arable and horticultural land occupied 0.043 m hectares or approximately 0.2% of total land area. In 2004, New Zealand pastures supported 4.45 m beef cattle, 5.15 m dairy cattle, 38.27 m sheep and 1.76 m deer.

New Zealand pastoral systems utilize a range of grass and legume species and cultivars, and specialist forage crops, the combination of which depends on location, soil type and fertility, weather conditions, availability of irrigation and production requirements. Of grasses, there are more than 60 perennial or long rotation ryegrass cultivars, 20+ Italian or short rotation ryegrass, and 15+ cultivars of other grass species including tall fescue, brome, cocksfoot and timothy. Similarly there is a range of white clover cultivars (20+) and other clover species, as well as pasture herb species. Specialist forage crops such as maize and brassicas support grass-based pasture production in many localities especially during winter and summer when pasture growth may be limited. There are more than 40 hybrid maize cultivars for grain or silage production, and a similar number of forage brassica cultivars. Forage brassica production is estimated to extend over 300,000 hectares in most years. Other forage crops include barley and oats.

Much of New Zealand's pastoral land can be regarded as intensively managed pasture, especially those on flat to rolling land where cultivation is possible. Pasture renewal typically follows a rotation of old pasture to short rotation ryegrass in autumn for winter green feed, to forage brassicas for summer green feed to autumn-sown perennial ryegrass/clover permanent pasture. Forage crops used in rotations vary with the production system and locality, e.g. in the North Island turnips and maize (for silage) dominate supplementary feed for dairy cows, while kale is the dominant forage crop for dairy cows in the South Island. The management of pests, weeds and diseases is often integrated with the pasture renewal cycle, as the establishment of forage crops and permanent pasture can be severely affected by pest organisms.

A comprehensive review of New Zealand pastures has recently been provided by Moot et al. (2010).

1.2 Historical use of pesticides on pastoral land

Pesticides[1] have long been used on pastoral and arable land in New Zealand to counteract the effects of pest[2] organisms. The last national survey of pesticide use in New Zealand conducted in 2004 estimated that approximately 1,278 tonnes of pesticide active ingredient from all pesticide classes was applied over 7.65 m hectares of pastoral land which averages to 0.17 kg of pesticide active ingredient per hectare, per year (Manktelow et al. 2005). In terms of total pesticide use in New Zealand, it was estimated 36% of all pesticides were applied to pastoral land in the 2004 survey year.

[1] A **pesticide** is defined as: any substance or mixture of substances represented by the registrant as suitable for the eradication of control of any pest, whether by way of modification of behaviour or development or otherwise; and includes any substance or mixture of substances represented by the registrant as suitable for use as a plant growth regulator, or a defoliant, or a desiccant and also any other substance to which s112 of the Agricultural Compounds and Veterinary Medicines Act 1997 applies (New Zealand Standard 8409: 2004. Management of Agrichemicals).

[2] A **pest** is defined as: an undesirable organism (bacterium, insect, fungus, nematode, weed, virus, animal) which is injurious to humans, desirable plants and animals, manufactured or natural products (New Zealand Standard 8409: 2004. Management of Agrichemicals).

The most significant use of insecticides occurs on dairy pastures, with relatively little insecticide being applied to non-dairy pasture or forage crops. Overall, less than 80 tonnes of insecticide active ingredient were applied to all pastoral sectors during the 2004 survey year.

Table 1: Pastoral sector-based pesticide use estimates (extracted from Appendix 12, Manktelow 2005).

Pastoral sector	Herbicides		Insecticides[1]		Fungicides	
	T a.i./yr	kg a.i./ha	T a.i./yr	kg a.i./ha	T a.i./yr	kg a.i./ha
Dairy	316.27	0.22	76.04	0.05	0.0	0.0
Deer	25.25	0.12	0.03	0.0	0.0	0.0
Sheep and beef	681.07	0.12	0.73	0.0	0.0	0.0
Cereal, silage or balage	80.97	1.97	1.62	0.04	11.86	0.29
Forage brassica	14.40	1.44	0.1	0.01	4.27	0.43
Maize, silage or balage	65.01	3.84	0.47	0.03	0.34	0.02
TOTALS	**1182.97**		**78.99**		**16.47**	

[1]These totals may include small volumes of chemicals used as molluscicides, but it was not possible to segregate these from data presented by Manktelow et al. (2005).

1.3 Major arthropod pests of pasture and forage crops

Both native and introduced arthropod pests inhabit and cause damage to pasture and forage crops in New Zealand. A critical period for protection of pasture and forage crops is during seedling establishment, and a range of soil-dwelling and rapid-invader species can cause significant seedling damage and loss. Established crop and pasture plants are also vulnerable to attack by arthropods, as are specialist seed crops. The following table summarizes the key arthropod pests of pasture and forage crops, and identifies features which contribute to their pest status. More comprehensive summaries of pests of pasture and forage crops may be found in Scott (1984). Mollusc pests are not included in the main body of this report, however, refer to Appendix 1.

Table 2: Major arthropod and other pests of New Zealand pasture and forage crops.

Taxanomic group	Common name[1]	Damaging stage(s)[2]	Type of damage[3]	Generations per year[4]	Pest status in NZ[5]	Pasture, crop attacked[6]
Coleoptera	grass grub	late larval instars	Root pruning, autumn, winter	one	Widespread, persistent	pasture, forage crops
	black beetle	Late larval instars, adults	Root pruning, summer, spring	one	Localized, sporadic/chronic	pasture, forage crops
	Tasmanian grass grub	Late larval instars	Defoliating, winter	one	Localized, sporadic	pasture
	Other scarabs	Late larval instars	Root pruning, autumn, winter	one	Localized, sporadic	pasture
	Argentine stem weevil	Larval instars	Stem boring, summer, autumn	2-3	Wide spread, persistent	pasture
	Whitefringed weevil	Laval instars	Root pruning	One over two years	Localized, sporadic	pasture, forage crops
	Sitona weevil	Larval instars	Root pruning, root nodules		Widespread, sporadic	forage crops
	Clover root weevil	Larval instars, adults	Root nodules, root pruning	1-2	Widespread, persistent	pasture
	Other weevils	Larval instars	Root feeding	1-2	Localized, sporadic	Pasture, forage crops
	Wireworm species	Larval instars	Root feeding	1-2	Localized, sporadic	Pasture, forage crops

Lepidoptera	Porina species	Late larval instars	Defoliating, autumn, winter	one	Localized, sporadic/chronic	Pasture
	Armyworm species	Larval instars	Defoliating, spring, summer	2-3	Localized, sporadic	Pasture, forage crops
	Cutworm species	Larval instars	Defoliating, spring, summer	2-3	Localized sporadic	Forage crops
	Corn earworm	Larval instars	Defoliating, spring, summer	2-3	Localized sporadic	Forage crops
	Clover case bearer moth	Larval instars	Seed feeding, summer	two	Localized, sporadic	Clover seed crops
	Diamond-back moth	Larval instars	Defoliating, spring, summer	6-7	Widespread, persistent	Forage crops
	White butterfly	Larval instars	Defoliating, summer	3-4	Widespread, sporadic	Forage crops
	Other caterpillars	Larval instars	Defoliating	2-4	Localized, sporadic	Pasture, Forage crops
Diptera	Australian soldier fly	Larval instars	Root feeding, summer, autumn	one	Localized, sporadic	Pasture, Forage crops
	Leafminer species	Larval instars	Leaf mining	unknown	Widespread, sporadic	Forage crops
Orthoptera	Black field cricket	Nymphs, adults	Seed and foliage feeding, spring summer	one	Localized sporadic	pasture
Thysanoptera	Thrips species	Adults, nymphs	Foliage feeding, spring, summer	many	Widespread, sporadic	Pasture, forage crops
Hemiptera	Various species	Adults , nymphs	Foliage and root feeding species, virus vectors, spring -autumn	many	Widespread, persistent	Pasture, forage crops
	Mealybug	Adults, nymphs	Root feeding, all year	unknown	Widespread, sporadic	Pasture
	Mirid species	Adults , nymphs	Foliage feeding, spring summer	2-3	Widespread, sporadic	Forage crops
	Green vegetable bug	Adults, nymphs	Foliage feeding, spring, summer	2-3	Localized, sporadic	Forage crops
Collembola	Springtail species	Adults, nymphs	Foliage feeding, spring, autumn	unknown	Widespread, sporadic	Forage crops
Other pests						
	Redlegged earth mite	Adults, immatures	Foliage feeding, spring, autumn	2-3	Localized, sporadic	Forage crops
	Nematode species	Adults, immatures	Root feeding, all year	2-3	Widespread, persistent	Pasture, forage crops

[1] The common names follow the Handbook of New Zealand Insect Names (Scott, RR & Emberson RM, (1999).
[2] Refers to the life cycle stage(s) which cause economic damage. Note that controls are commonly targeted at earlier life cycle stages before economic loss occurs.
[3] Refers to how and when the main damaging stage(s) cause damage.
[4] The number of generations per year depends on local weather conditions and may vary from one part of the country to another.
[5] The pest status of pests is often difficult to quantify, and will often vary depending on local soil and weather conditions. Information in this column tries to reflect overall how widespread and persistent a pest is.
[6] Specific pests may commonly be found in pasture, but attack primarily one plant species. Similarly for forage crops, some crops will be infested more commonly than others.

Table 2 above shows a broad variety of pests attack pasture and forage crops in New Zealand, but are dominated by species from the orders Coleoptera, Lepidoptera and Hemiptera. Pests from these orders vary widely in their distribution and persistence with some being widespread and damaging over extended periods while others are sporadic and prone to localized but often severe outbreaks. These factors strongly influence the strategies for pest management, and the types of controls that have been developed through research and development. With persistent and widespread pests, for example, biological control and pasture management strategies have been developed to combat these pests. In contrast, localized and sporadic pests are commonly controlled using insecticides.

The target life cycle stage for pasture and forage crop pests is typically larval or nymphal stages as these stages are more damaging than adults in most cases. Depending on the pest species and the plant species they attack, both foliage and roots of pasture and forage crops are attacked. Most species are chewing pests, with the exception of hemipterans that feed with piercing-sucking mouth parts. The mode of feeding becomes significant when insecticides are used for control, e.g., systemic insecticides are more effective against piercing-sucking insects.

1.4 Role of insecticides in pasture insect pest management

Insecticides have traditionally played an important role in the management of pasture and forage crops pests (see section 2.1 for further information). Often these have been applied when pastures or forage crops are established to protect vulnerable seedlings, but established crops and pastures have also been treated with insecticides to reduce resident and damaging pest populations. The effective management of many pasture and forage crop pests poses a range of challenges for farmers, viz.:

- The damaging larval stages are often concealed (in soil, stems, root nodules, seeds) and are difficult to detect.
- Failure to detect insect and other pests can result in poor pasture or forage crop establishment and production, thereby affecting the capacity to support livestock.
- Some pests occur sporadically and cause large outbreaks, which are often invoked by suitable weather conditions, and require immediate and rapid action to minimize pest damage.
- For a range of pests, few alternative controls to insecticides are available, or if they are available their effectiveness may be limited or they not able to be applied at a particular time, e.g., some cultural controls. Furthermore, they may not be sufficiently quick-acting to contain pest outbreaks, or protect sufficiently establishing seedling plants.

Insecticides afford many advantages in insect pest management, and can resolve the challenges noted above. These advantages include:

- A broad range of registered insecticide products for most common pasture and forage crop pests.
- A range of formulations and types of action from which specific products can be selected to effectively control specific types of pests under a range of different production systems and conditions.
- Highly effective protection of pasture and forage crops during establishment.
- Quick action by most insecticides (except growth regulators) that can affect rapid control following application and thereby limit pest outbreaks.

Although insecticides might be viewed by farmers as the most effective way of managing most insect pests of pasture and forage crops, there are concerns regarding the sustainability of using insecticides including:

- The cost of insecticide inputs relative to returns.
- The possibility of pests developing resistance to insecticides following repeated use.
- The possibility that residues may accumulate in livestock and affect their marketability.
- The potential disruption of other pest control methods, especially biological control agents.
- The possibility that some older products may be de-registered, leaving few if any viable controls.
- Other commercial or regulatory constraints that may in future limit the use of some insecticides.

In principle, insecticides should be viewed as the last course of action available to combat pests in any production system. Early recognition of pest problems can widen the choice of control methods and, whenever possible, insecticides should be integrated with alternative control measures to limit their use and maximize their long-term effectiveness in integrated pest management.

1.5 Summary points for Section 1

- Pesticides (insecticides, fungicides and herbicides) have been used widely over pastoral land in New Zealand for the past 60 years to protect pasture and forage crops from pests (insects, fungi, and weeds). Intensification of pastoral land production would not have been possible without pesticides.
- In 2004, approximately 1,278 tonnes of pesticide active ingredient from all pesticide classes (insecticides, herbicides and fungicides, others) was applied over 7.65 m hectares of pastoral land which averages to 0.17 kg of pesticide active ingredient per hectare, per year.
- In 2004, approximately 79 tonnes of insecticide active ingredient was applied to pastoral land, the majority of which (76 tonnes) was applied to dairy pasture (on average approximately 0.05 kg active ingredient, per hectare, per year).
- A broad variety coleopteran, lepidopteran and hemipteran and other species of native and introduced origin attack the roots, stems, leaves and seeds of pasture and forage crops. Some pests are widespread and persistent, while others are more localized and occur sporadically.
- Insecticides have many distinct advantages over other methods of control for pasture and forage pests, and when used effectively provide good economic returns. However, the longer term availability of many insecticides is uncertain.

2.0 Insecticides registered for use on pastures and forage crops

2.1 Historical insecticide research and registration trends

The intensification of New Zealand agriculture has been in progress since the colonization by European immigrants in the mid to late 1800s. Several phases in the intensification and diversification of New Zealand agriculture have been recognized (MacLeod and Moller 2006), and in pastoral farming the increasing use of fertilizers and pesticides after World War II was a particular feature. In the 10-15 years that followed the World War II, DDT and other organochlorines were extensively used to suppress many insect pests of crops and pastures. DDT was often applied in combination with fertilizer, however, by the early 1960s concern about the environmental effects of such insecticides was being expressed world-wide. Although banned from use in 1970, a legacy of DDT residues remains in many New Zealand soils (Boul 1994).

Research on pasture and forage crop pests in New Zealand is well chronicled in the New Zealand Plant Protection Society's conference proceedings (now called New Zealand Plant Protection www.nzpps.org). Publications reporting the efficacy of insecticides against pasture insect pests, especially for grass grub and porina, were numerous from the mid-1960s onwards when the focus was on testing organphosphate insecticides. During the 1970s and 1980s, there were regular reports on the efficacy of insecticides against other pasture pests such as Australian soldier fly, black beetle, whitefringed weevil, Argentine stem weevil, armyworm, black field cricket, as well as lucerne and forage crop pests such as aphids and caterpillar pests. Since the 1990s to the present, there have been significantly fewer reports on insecticides of pasture or forage crop pests with a greater emphasis on biological control and other aspects of their biology, ecology and management.

The trend in insecticide registrations for use on pasture and forage crops can be traced through published pesticide manuals (New Zealand Agrichemical and Plant Protection Manual 1984-1993; Novachem Manual 1994 to present). For the period 1984-2010, there was one organochlorine, 11 organophosphate, four carbamate, one pyrethroid, two neonicotinoid, one benzoyl phenyl urea and one microbial insecticide registered for use on pastures (Table 3). Some active ingredients that were available in 1984 are no longer commercially available or have had their registrations revoked, e.g., carbofuran, fensulfothion, endosulfan and lindane. Similarly, for forage crops for the period 1984-2010 there was one organochlorine, 24 organophosphate, four carbamate, eight pyrethroid, two neonicotinoid, and one microbial insecticide registered (Table 4). Notable differences between insecticides registered for pastures and forage crops are the total number of insecticides registered (pasture 23, forage crops 40), and the greater range of organophosphate and pyrethroid insecticides registered for forage crops which likely reflects the diversity of lepidopteran and hemipteran pests found on forage crops.

For both pasture and forage crops, organophosphate insecticides have dominated the range of insecticides available. This generally reflects the broad spectrum, contact and/or systemic action of insecticides in this class. Notable also is their contact action against soil-dwelling pest stages, e.g., diazinon and chlorpyrifos. Those with systemic action like phorate and the carbamate insecticide oxamyl for many years have similarly provided effective control of many piercing-sucking pests like aphids when drilled as granular formulations with seed. Both organophosphate and carbamate insecticides are under review by the Environmental Risk Management Authority (see section 2.4).

Table 3: History of insecticides registered for use on pastures in New Zealand since 1984. (Sources: New Zealand Agrichemical and Plant Protection Manual 1984, 1987, 1990, Novachem Manual 1994, 1996, 1998, 2000, 2004, 2006, 2008, 2010).

Active ingredient	Chemical class	1984	1987	1990	1994	1996	1998	2000	2002	2004	2006	2008	2010
diflubenzuron	Benzoyl phenyl urea			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
carbofuran	Carbamate	Y	Y										
furathiocarb	Carbamate			Y	Y	Y	Y	Y	Y	Y	Y	?	Y
methomyl	Carbamate	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
oxamyl	Carbamate	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Serratia sp	Microbial					Y	Y	Y	Y	y	y	Y	Y
clothianidin	Neonicotinoid												Y
imidacloprid	Neonicotinoid				y	Y	Y	Y	Y	Y	Y	Y	Y
lindane	Organochlorine	Y	Y										
chlorpyrifos	Organophosphate	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
demeton-s-methyl	Organophosphate				y	Y	Y						
diazinon	Organophosphate	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
dimethoate	Organophosphate	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
fenamiphos	Organophosphate	Y	Y	y	y	y	y	y	y				
fenitrothion	Organophosphate	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
fensulfothion	Organophosphate	Y	Y										
isazophos	Organophosphate	Y	Y	Y	Y	Y	Y	Y					
maldison	Organophosphate	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
omethoate	Organophosphate		Y	Y	Y	Y	Y						
phorate	Organophosphate	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
terbufos	Organophosphate		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
trichlorfon	Organophosphate					y	y	y	y	y	y	y	Y
alpha-cypermthrin	Pyrethroid							Y	Y	Y	Y	Y	Y

[1] The following chemicals were listed in the respective agrichemical manuals, however, it does not confirm products containing the active ingredient were first registered at that time or were commercially available.

Table 4: History of insecticides registered for use on forage and seed crops in New Zealand since 1984. (Sources: New Zealand Agrichemical and Plant Protection Manual 1984, 1987, 1990, Novachem Manual 1994, 1996, 1998, 2000, 2004, 2006, 2008, 2010).

Active ingredient	Chemical class	1984	1987	1990	1994	1996	1998	2000	2002	2004	2006	2008	2010
carbaryl	Carbamate	Y	y	y	y	y	y	y	y	y	y	y	y
carbofuran	Carbamate	Y	y										
furathiocarb	Carbamate						y	y	y	y	y	y	y
pirimicarb	Carbamate	Y	y	y	y	y	y	y	y	y	y	y	y
endosulfan	Cyclodiene	Y	y	y	y	y	y	y	y	y	y	y	
Bacillus thuringiensis	Microbial							y	y	y	y		
imidacloprid	Neonicotinoid					y	y	y	y	y	y	y	y
thiamethoxam	Neonicotinoid												y
acephate	Organophosphate	Y	y	y									
azinphos-methyl	Organophosphate	Y	y	y	y	y	y	y	y				
bromophos	Organophosphate	Y											
chlorpyrifos	Organophosphate	Y	y	y	y	y	y	y	y	y	y	y	y
demeton-s-methyl	Organophosphate	Y	y	y	y	y	y						
diazinon	Organophosphate	Y	y	y	y	y	y	y	y	y	y	y	y
dichlorvos	Organophosphate	y	y	y	y	y	y	y	y	y	y	y	y
dicrotophos	Organophosphate	Y	Y										
dimethoate	Organophosphate	Y	y	y	y	y	y	y	y	y	y	y	y
disulfoton	Organophosphate	Y	y	y	y	y	y						
fenamiphos	Organophosphate		y	y				y	y	y	y	y	
fenitrothion	Organophosphate			y	y	y	y	y	y	y	y	y	y
fensulfothion	Organophosphate		y										
isazophos	Organophosphate		y		y	y	y	y					
maldison	Organophosphate	Y	y	y	y	y	y	y	y	y	y	y	y
methamidaphos	Organophosphate	Y	y	y	y	y	y	y	y	y	y	y	y
methomyl	Organophosphate	Y	y	y	y	y	y	y	y	y	y	y	y
mevinphos	Organophosphate	Y	y	y									
omethoate	Organophosphate	Y	y	y	y	y	y						

Table 4 continued

parathion	Organophosphate					y	y	y	y	y	y		
phorate	Organophosphate	Y	y	y	y	y	y	y	y	y	y	y	y
terbufos	Organophosphate		y	y	y	y	y	y	y	y	y	y	y
thiometin	Organophosphate	Y	y	y				y	y				
trichlorfon	Organophosphate								y	y	y	y	y
alpha-cypermethrin	Pyrethroid								y	y	y	y	y
cyfluthrin	Pyrethroid	Y	y	y	y	y	y	y	y	y			
deltamethrin	Pyrethroid	Y	y	y	y	y	y	y	y	y	y	y	y
es-fenvalerate	Pyrethroid				y		y	y	y		y	y	y
fenvalerate	Pyrethroid	Y	y	y	y	y	y						
lambda-cyhalothrin	Pyrethroid				y	y	y	y	y	y	y	y	y
permethrin	Pyrethroid	Y	Y	y									
tau-fluvalinate	Pyrethroid				y	y		y	y	y	y	y	y

[1] The following chemicals were listed in the respective agrichemical manuals, however, it does not confirm products containing the active ingredient were first registered at that time or were commercially available.

2.2 Currently-registered insecticides for pasture and forage crop pests

(Note: This section includes insecticides of chemical or microbial origin. It also includes one registered nematicide, but excludes molluscicides.)

In 2010, 28 insecticidal active ingredients (two products have two active ingredients) were available in over 60 commercial products for the control of pasture and forage crop pests (Table 5). All but one (*Serratia*) are synthetic chemicals most of which are available as liquid formulations (emulsifiable concentrate, oil in water emulsion, aqueous concentrate, suspension concentrate, capsule suspension) or granular formulations (water dispersible granule, granule, controlled release granule). Several insecticides, e.g., diazinon and chlorpyrifos are available as liquid and granular formulations to suit particular application methods.

Of the 28 insecticide active ingredients, there are 12 organophosphates, five carbamates, six pyrethroids, three neonicotinoids, one benzoyl phenyl urea and one microbial insecticide, of which nine are registered for use on pasture, and six specifically for grass seed and five for clover (Table 6). For forage crops, seven insecticides are registered for lucerne, 11 for cereals, 15 for maize and 20 for forage brassica. Of the 28 insecticides, most have multiple registered uses in pasture and forage crops, although diflubenzuron, oxamyl and *Serratia* are only registered for use on pasture.

Twenty six species, or specified groups of pests, e.g., aphids, springtails (which contain more than one species) are identified on label claims for pests of pasture and forage crops (Table 7). Aphids (mainly on forage crops) have the most insecticide registrations (16), followed by springtails (11), armyworms (9), Argentine stem weevil (8), grass grub (8), diamondback moth (8), corn earworm (7), white butterfly (7), cutworm (7), wheat bug (6), porina (5), black beetle (3), sitona weevil (3), Tasmanian grass grub (3), other unspecified weevils (3), plant parasitic nematodes (2), clover casebearer moth (2), clover root weevil (1), green vegetable bug (1), mirids (1), brassica leafminer (1), black field cricket (1), thrips (1), redlegged earth mite (1), and other unspecified caterpillars (1). Generally, more insecticides are registered for forage crop pests than pasture pests. The number of insecticides registered for particular pest species or groups of species likely reflects their abundance, capacity for increase and potential to cause damage directly (or indirectly through vectoring plant pathogens, e.g., aphids), and the availability of reliable non-chemical control methods.

The Hazardous Substances and New Organisms Act 1996 (HSNO) rates pesticides according to a hazard classification system. Table 8 summarizes the hazard ratings according to acute mammalian toxicity (Class 6.1, toxicity to aquatic life (Class 9.1), toxicity to the soil environment (Class 9.2), toxicity to terrestrial vertebrates (Class 9.3) and toxicity to terrestrial invertebrates (Class 9.4). Most insecticides listed in Table 8 are nerve poisons and are thus rated as toxic to humans (6.1D), very toxic (6.1C), highly toxic (6.1B) or extremely toxic (6.1A). Only the insect growth regulator diflubenzuron and the microbial product containing *Serratia* are not rated hazardous to humans. Similarly, all insecticides are rated toxic (9.1B) or very toxic (9.1A) to aquatic life, while the *Serratia* product is rated as slightly harmful to aquatic life. About half the insecticides listed are not rated as toxic to the soil environment (principally the pyrethroids, diflubenzuron and *Serratia*), while the remainder are mostly rated toxic (9.2B) to soil organisms. Interestingly, diazinon is only rated slightly harmful to soil organisms (9.2D), while imidacloprid is rated very toxic (9.2A) to soil organisms. Most insecticides listed are rated as toxic (9.3B) or very toxic (9.3A) to terrestrial invertebrates, and most are rated very toxic (9.4A) to terrestrial invertebrates with the exception in both classes being diflubenzuron and *Serratia* products. The *Serratia* based insecticide is the only product not requiring an approved handler to manage the application of these insecticides.

Table 5: Insecticides registered in New Zealand for use on insect pests of pastures and forage crops (Novachem Manual, web version 2010).

Active ingredient	Chemical class	Trade products[1]	Formulations[2]
carbaryl	Carbamate	Carbaryl 50F, Seven Flo	SC
diflubenzuron	Benzoylurea	Diffuse 25WP, Dimilin 25W, Porinex, Sniper, Dimilin 2L	SC
furathiocarb	Carbamate	Promax 400CS	CS
methomyl	Carbamate	Lannate L	AC
oxamyl	Carbamate	Vydate L	AC
pirimicarb	Carbamate	Pirimicarb, Pirimor 50	WG
Serratia	Microbial	Bioshield Grass Grub	G
clothianidin	Neonicotinoid	Poncho	SC
imidacloprid	Neonicotinoid	Acclaim, Gaucho, Sombrero 600 Seed Dressing,	SC
thiamethoxam	Neonicotinoid	Cruiser 600FS	SC
chlorpyrifos	Organophosphate	e.g., Chlorpyrifos 100 EC, Lorsban 50 EC, Lorsban 750 WG, Pyrifos G, SusCon Green	EC, WG, CS, CG
diazinon	Organophosphate	e.g., Dew 500, Diazinon 20G, Gesapon 20G, Diazinon 800, Diazinon 800 EC, Diazinon EC, Diazonyl 60 EC, Digrub, Diazol	EW, EC, G,
dichlorvos	Organophosphate	Divap, Nuvos	EC
dimethoate	Organophosphate	Dimezyl 40EC, Perfekthion S, Rogor E	EC
fenamiphos[3]	Organophosphate	Nemacur, Nematak 400EC	EC
fenitrothion	Organophosphate	Caterkil 1000	EC
maldison	Organophosphate	Malathion 50EC	EC
methamidaphos	Organophosphate	Tamaron, Metafort 60 SL	AC
phorate	Organophosphate	Crop Care Phorate 20G, Disect, Nufarm Phorate, Thimet 20G	G
terbufos	Organophosphate	Counter 20G	G
trichlorfon	Organophosphate	Trifon	EW
alpha-cypermethrin	Pyrethroid	e.g., Alpha-Cypermethrin 100, Bestseller 100 EC, Cypher, Cypher EW, Dominex PC100, Fastac, Alpha-Scud	EC, EW
deltamethrin	Pyrethroid	Ballistic, Decis Forte, Deltaphar 25EC	EC
es-fenvalerate	Pyrethroid	Sumi-Alpha	EC
lambda-cyhalothrin	Pyrethroid	Cyhella, Karate with Zeon Technology	CS
tau-fluvalinate	Pyrethroid	Mavrik Aqua Flo	EW
lambda-cyhalothrin/primicarb	Pyrethroid/carb	Dovetail	EC
permethin/primiphos-methyl	Pyrethroid/OP	Attack	EC

[1]Examples of trade products are listed, and may not include all products available on the market for a particular active ingredient as these can change over time.
[2] Abbreviations for formulation type are: **AC** aqueous concentrate, **CG** controlled-release granule, **CS** capsule suspension, **EC** emulsifiable concentrate, **EW** oil in water emulsion, **G** granule, **WG** water dispersible granule [3] Fenamiphos is registered as a nematicide.

Table 6: Insecticides registered for use on pastures and forage crops in New Zealand (Novachem Manual, web version 2010).

Active ingredient	Chemical class[1]	MoA class[2]	Pasture	Ryegrass[3]	Clover[3]	Lucerne	Cereal[4]	Maize[4]	Brassica[5]
diflubenzuron	Benzoylurea	15	Y						
carbaryl	Carbamate	1A						Y	
furathiocarb	Carbamate	1A		Y	Y			Y	Y
methomyl	Carbamate	1A	Y				Y	Y	
oxamyl	Carbamate	1A	Y	Y					
pirimicarb	Carbamate	1A				Y	Y		Y
Serratia	Microbial		Y						
clothianidin	Neonicotinoid	4A		Y			Y	Y	Y
imidacloprid	Neonicotinoid	4A		Y			Y	Y	Y
thiamethoxam	Neonicotinoid	4A						Y	Y
chlorpyrifos	Organophosphate	1B	Y	Y	Y	Y	Y	Y	Y
diazinon	Organophosphate	1B	Y				Y		Y
dichlorvos	Organophosphate	1B			Y		Y		Y
dimethoate	Organophosphate	1B				Y			Y
fenamiphos	Organophosphate	1B				Y			
fenitrothion	Organophosphate	1B	Y			Y			Y
maldison	Organophosphate	1B	Y						Y
methamidaphos	Organophosphate	1B						Y	
phorate	Organophosphate	1B	Y			Y		Y	Y
terbufos	Organophosphate	1B	Y				Y	Y	Y
trichlorfon	Organophosphate	1B	Y	Y			Y	Y	Y
alpha-cypermethrin	Pyrethroid	3	Y					Y	
deltamethrin	Pyrethroid	3				Y		Y	Y
es-fenvalerate	Pyrethroid	3						Y	Y
lambda-cyhalothrin	Pyrethroid	3			Y		Y	Y	Y
tau-fluvalinate	Pyrethroid	3			Y				Y
lambda-cyhalothrin/primicarb	Pyrethroid/carbamate	3/1A					Y		Y
permethin/primiphos-methyl	Pyrethroid/organophosphate	3/1B							Y

[1] Chemical class indicating chemical structure and mode of action.
[2] IRAC (www.irac-online.org) mode of action class. MoA class numbers are referred to for resistance management.
[3] Refers to grass seed that is primarily sown for pasture. Specific mention is made elsewhere when applications are made to grass seed crops.
[4] Refers primarily to crops that may be grazed by animals or used for silage or balage.
[5] Refers only to forage brassicas (turnip, kale, rape, etc.) and not horticultural brassicas.

Table 7: Insecticides registered for use on insect pests of pastures and forage crops in New Zealand (Novachem Manual, web version 2010).

Active ingredient	Class	ASW	BB	CRW	GG	SW	TGG	WEV	AW	CAT	CCB	CEW	DBM	GCW	POR	WB	APH	GVB	NWB	MIR	ASF	BLM	BFC	THR	SPR	REM	NEM
diflubenzuron	BU														Y										Y		
oxamyl	CA	Y																									
carbaryl	CA								Y			Y															
furathiocarb	CA	Y																							Y		Y
pirimicarb	CA																Y										
Serratia	MI				Y																						
clothianidin	NE	Y	Y		Y									Y											Y		
imidacloprid	NE	Y	Y		Y												Y		Y						Y		
thiamethoxam	NE	Y															Y								Y		
chlorpyrifos	OP	Y		Y	Y	Y	Y		Y			Y		Y	Y		Y		Y						Y		
diazinon	OP				Y				Y				Y		Y		Y								Y		
dichlorvos	OP									Y	Y						Y										
dimethoate	OP																Y								Y		
fenamiphos	OP																										Y
fenitrothion	OP					Y	Y	Y	Y						Y		Y		Y						Y		
maldison	OP												Y			Y	Y						Y				
methamidaphos	OP								Y								Y	Y									
methomyl	OP								Y			Y		Y													
phorate	OP	Y	Y		Y			Y									Y		Y		Y				Y		
terbufos	OP	Y			Y			Y									Y		Y						Y		
trichlorfon	OP								Y			Y	Y	Y	Y	Y											
alpha-cypermethrin	PY						Y		Y			Y		Y												Y	
deltamethrin	PY					Y						Y	Y	Y		Y	Y										
es-fenvalerate	PY								Y			Y	Y			Y											
lambda-cyhalothrin	PY												Y	Y		Y	Y			Y				Y			
tau-fluvalinate	PY										Y						Y										
lambda-cyhalothrin/primicarb	PY/ CA												Y			Y	Y										
permethin/primiphos-methyl	PY/ OP												Y			Y			Y			Y					

Abbreviations for pests: **ASW** Argentine stem weevil, **BB** black beetle, **CRW** clover root weevil, **GG** grass grub, **SW** sitona weevil, **TGG** Tasmanian grass grub, **WEV** weevil unspecified, **AW** armyworm, **CAT** caterpillar unspecified, **CCB** clover casebearer moth, **CEW** corn earworm, **DBM** diamondback moth, **GCW** greasy cutworm, **POR** porina, **WB** white butterfly, **APH** aphids all species, **GVB** green vegetable bug, **NWB** Nysius wheat bug, **MIR** mirid, **ASF** Australian soldier fly, **BLM** brassica leafminer, **BFC** black field cricket, **THR** thrips, **SPR** springtails all species, **REM** red-legged earth mite, **NEM** nematodes all species. **Chemical class abbreviation**: BU benzoyl phenyl urea, CA carbamate, MI microbial, NE neonicotinoid, OP organophosphate, PY pyrethroid.

Table 8: The mode of action and toxicity to mammals, aquatic life, the soil environment, terrestrial invertebrates and terrestrial invertebrates of insecticides registered for use on pests of pasture and forage crops in New Zealand.

Active ingredient	**Chemical class**	**Mode of action**			**HSNO classes[1]**			**Approved**
			Class 6.1	Class 9.1	Class 9.2	Class 9.3	Class 9.4	**Handler needed**
diflubenzuron	Benzoylurea	Growth regulation		9.1A				yes
carbaryl	Carbamate	Nerve poison	6.1C	9.1A	9.2B	9.3B	9.4A	yes
furathiocarb	Carbamate	Nerve poison	6.1C	9.1A	9.2B	9.3A	9.4A	yes
methomyl	Carbamate	Nerve poison	6.1C	9.1A	9.2B	9.3B	9.4A	yes
oxamyl	Carbamate	Nerve poison	6.1B	9.1B	9.2B	9.3A	9.4A	yes
pirimicarb	Carbamate	Nerve poison	6.1C	9.1A		9.3A	9.4C	yes
Serratia	Microbial	Feeding disruption		9.1D				no
clothianidin	Neonicotinoid	Nerve poison	6.1D	9.1A	9.2B	9.3C	9.4A	yes
imidacloprid	Neonicotinoid	Nerve poison	6.1C	9.1A	9.2A	9.3B	9.4A	yes
thiamethoxam	Neonicotinoid	Nerve poison	6.1E	9.1B		9.3C	9.4A	yes
chlorpyrifos	Organophosphate	Nerve poison	6.1C	9.1A	9.2B	9.3A	9.4A	yes
diazinon	Organophosphate	Nerve poison	6.1C	9.1A	9.2D	9.3A	9.4A	yes
dichlorvos	Organophosphate	Nerve poison	6.1A	9.1A		9.3A	9.4A	yes
dimethoate	Organophosphate	Nerve poison	6.1D	9.1A	9.2B	9.3A	9.4A	yes
fenamiphos	Organophosphate	Nerve poison	6.1B	9.1A	9.2B	9.3A	9.4A	yes
fenitrothion	Organophosphate	Nerve poison	6.1C	9.1A		9.3A	9.4A	yes
maldison	Organophosphate	Nerve poison	6.1D	9.1A		9.3B	9.4A	yes
methamidaphos	Organophosphate	Nerve poison	6.1B	9.1A	9.2B	9.3A	9.4A	yes
phorate	Organophosphate	Nerve poison	6.1A	9.1A	9.2B	9.3A	9.4B	yes
terbufos	Organophosphate	Nerve poison	6.1A	9.1A		9.3A	9.4C	yes
trichlorfon	Organophosphate	Nerve poison	6.1C	9.1A	9.2B	9.3A	9.4C	yes
alpha-cypermethrin	Pyrethroid	Nerve poison	6.1D	9.1A		9.3B	9.4A	yes
deltamethrin	Pyrethroid	Nerve poison	6.1D	9.1A		9.3C	9.4A	yes
es-fenvalerate	Pyrethroid	Nerve poison	6.1D	9.1A		9.3C	9.4A	yes
lambda-cyhalothrin	Pyrethroid	Nerve poison	6.1C	9.1A		9.3B	9.4A	yes
tau-fluvalinate	Pyrethroid	Nerve poison	6.1D	9.1A		9.3C		yes
lambda-cyhalothrin/primicarb	Pyrethroid/carbamate	Nerve poison	6.1D	9.1A		9.3B	9.4C	yes
permethin/primiphos-methyl	Pyrethroid/OP	Nerve poison	6.1D	9.1A		9.3A	9.4A	yes

[1] HSNO classifications that indicate **acute toxicity** (Class 6.1**), toxicity to aquatic life** (Class 9.1), **toxicity in the soil environment** (Class 9.2), **toxicity to terrestrial vertebrates** (Class 9.3), **toxicity to terrestrial invertebrates** (Class 9.4). NOTE: formulations of different trade products may differ slightly in hazard classification depending on their constituents. The most hazardous formulation is used here for the purpose of this report. Refer to the label for the specific hazard classification for individual trade products. A space in a column means no classification in that category.

2.3 Insecticides registered for specific pasture and forage crop pests

2.3.1 Argentine stem weevil, *Listronotus bonariensis* (Kuschel) [Coleoptera: Curculionidae]

Pest status

Argentine stem weevil (ASW), an introduced pest of grasses and cereals, is found throughout New Zealand. Larvae cause damage to the tillers of grasses and cereals by burrowing internally; several tillers may be destroyed by one larva during its development. Adults may cause superficial damage on leaves. Two generations per year occur in most parts of New Zealand in spring/early summer and summer/early autumn. Since the selection and development of grass cultivars containing endophytic fungi that confer some resistance to ASW and the introduction of a parasitoid that attacks adults, damage by ASW is less severe in some pastures nowadays. Maize, cereal and grass crops without resistance to ASW are especially susceptible at the seedling stage. The productivity of ryegrass seed crops may also be reduced by ASW larvae feeding in reproductive tillers. Damage is reputedly caused by adults to brassica seedlings.

Role of insecticides

Control of ASW in grass and cereal crops is primarily focused on protection of seedlings using systemic insecticides to target larvae, either applied as granules with seed at drilling (phorate), as a spray after seedling emergence (oxamyl), or as a seed dressing applied before drilling (furathiocarb, clothianidin, imidacloprid, thiamethoxam). Only one insecticide with contact action (chlorpyrifos) is targeted at adults to reduce egg laying, however, determining the presence of adults and eggs requires sampling and inspection of tillers for the presence of eggs.

The recommended rates of insecticide for granular formulations vary between 1.0-2.0 kg active ingredient per hectare. By contrast, insecticides applied as seed dressings are applied at rates in the order of grams of active ingredient per hectare (depending on the seed treatment and sowing rates). The withholding periods for all granular and seed dressing formulations is 42 days, which should pose no risk to grazing stock under normal pasture and forage crop management practices. The withholding period for spray formulations is 7 days.

Oxamyl may be applied as a spray to existing pasture to reduce ASW populations before direct drilling new crops or pasture that are susceptible to this pest.

Factors affecting efficacy

For seed dressings, insecticides should be applied using properly calibrated seed treatment machines. Calibration of seed drilling equipment is also required as seed dressings may alter seed sowing rate. Adequate soil moisture is required to allow seedling growth and uptake of seed dressing or granular insecticide.

No cases of resistance by ASW to insecticides have been recorded, and the risk of resistance development is likely to be low very low due to low insecticide selection pressure being placed on this pest.

Summary

Management of ASW in pasture, seed and forage crops by insecticides is possible with seven different active ingredients, four of which are used as seed dressings before sowing. The possible future removal of older organophosphate and carbamate insecticides could reduce the range of available products.

Table 9: Insecticides registered for Argentine stem weevil (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Pasture	Pasture	Pasture	Pasture	Pasture	Pasture	Pasture	Pasture
	chlorpyrifos	Lorsban 750 WG	0.8 kg	0.6 kg	Apply when adults begin to lay eggs on tillers.	Apply in 100-200 litres water per hectare.	7 days
	oxamyl	Vydate L	2.0 litres	0.48 kg	At first sign of larval damage.	May also be applied before cultivation or direct drilling.	7 days
	phorate	Thimet 20 G	5.0 kg	1.0 kg	Apply In furrow at sowing.	Not very effective against grass grub when populations high.	42 days
Grass seed[2]							
	clothianidin	Poncho	Seed treatment		Apply to seed before drilling.	Applied only as a seed treatment.	42 days
	furathiocarb	Promax 400 CS	25 ml/kg seed		Apply to seed before drilling.	Applied only as a seed treatment.	42 days
	oxamyl	Vydate L	2 litres	0.48 kg	At first sign of larval damage.	May also be applied before cultivation or direct drilling.	7 days
Forage crops							
brassica	clothianidin	Poncho	Seed treatment		Apply to seed before drilling.	Applied only as a seed treatment.	42 days
brassica	imidacloprid	Gaucho Sombero 600	12-24 ml/kg seed		Apply to seed before drilling.	Mix with sufficient water to ensure thorough coverage of seed.	42 days
cereals	chlorpyrifos	Rampage Encaps	2.4 litres	0.6 kg	Apply when adults begin to lay eggs on tillers.		7 days
cereals	clothianidin	Poncho	Seed treatment		Apply to seed before drilling.	Applied only as a seed treatment.	42 days
maize	clothianidin	Poncho	Seed treatment		Apply to seed before drilling.	Applied only as a seed treatment.	42 days
maize	furathiocarb	Promax 400C S	30-55ml /kg seed		Apply to seed before drilling.	Applied only as a seed treatment.	42 days
maize	imidacloprid	Gaucho Sombero 600	580 ml/100 kg seed		Apply to seed before drilling.	Mix with sufficient water to ensure thorough coverage of seed.	42 days
maize	phorate	Thimet 20G	7.5-10 kilograms	1.05-2.0 kg	Band application at sowing.		42 days
maize	thiamethoxam	Cruiser 600 FS	Seed treatment		Apply to seed before drilling.	Applied only as a seed treatment.	42 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

[2] Grass seed here refers primarily to grass seed sown for pasture.

2.3.2 Black beetle *Heteronychus arator* (F.) [Coleoptera: Scarabaeidae]

Pest status

Black beetle, an introduced species, is found throughout the northern half of the North Island. Damage may be caused by both larvae and adults to the roots of pasture grasses, maize and other crops. The effect of larval feeding is similar to that of grass grub, but occurs primarily in summer in contrast to grass grub damage which occurs in autumn/winter. Damage by black beetle to pastures can be severe in areas where it is a persistent pest. In other areas black beetle is more sporadic in its occurrence and dependent on seasonal conditions. Damage by adults to maize seedlings can be severe when populations are high. There is one generation per year, and populations overwinter as adults. Development of larvae is influenced by soil conditions and individuals of each developmental stage can often be found at any time of the year. Peak emergence of adults is from March to May.

Role of insecticides

Although it has been demonstrated in the past that the broadcast application of granular insecticides can reduce populations of this pest in pasture, the sporadic nature and variable damage caused by this pest generally does not warrant regular application to pasture by this method. Instead, insecticidal control of black beetle has focused on protection of pasture and maize seedlings. Seedling protection can be effected by seed treatment (imidacloprid, clothianidin) or application of granular insecticide at sowing (phorate).

Seed treatments result in very low quantities of active ingredient being applied per hectare and provide protection of seedlings through systemic action. Phorate also acts systemically with some contact action likely with insects in the soil. The withholding periods for all granular and seed dressing formulations is 42 days, which should pose no risk to grazing stock under normal pasture and forage crop management practices.

Factors affecting efficacy

For seed dressings, insecticides should be applied using properly calibrated seed treatment machines. Calibration of seed drilling equipment is also required as seed dressings may alter seed sowing rate. Adequate soil moisture is required to allow seedling growth and uptake of seed dressing or granular insecticide.

For maize, phorate granules should be applied in a band above the seed and incorporated into the top two centimeters of soil to avoid contact with the seed.

No cases of resistance by black beetle to insecticides have been recorded, and the risk of resistance development is regarded as low.

Summary

There is a limited range of insecticide active ingredients registered for control of black beetle in pasture and maize crops. Control of this pest by insecticides is primarily focused on protection of grass and maize seedlings with seed dressings or granular insecticide. There is no immediate risk of withdrawal of insecticides for black beetle control.

Table 10: Insecticides registered for black beetle (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Grass seed[2]							
	imidacloprid	Gaucho Sombero 600	580 ml/100 kg seed		Apply to seed before drilling.	Mix with sufficient water to ensure thorough coverage of seed.	42 days
Forage crops							
maize	clothianidin	Poncho	Seed treatment		Apply to seed before drilling.	Applied only as a seed treatment.	42 days
maize	imidacloprid	Gaucho Sombero 600	580 ml/100 kg seed		Apply to seed before drilling.	Mix with sufficient water to ensure thorough coverage of seed.	42 days
maize	phorate	Thimet 20G	7.5-10 kg	1.5-2.0 kg	Band application at sowing for control of adults.	Best results when granules placed above seed and incorporated to 2 cm depth	42 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

[2] Grass seed here refers primarily to grass seed sown for pasture.

2.3.3 Clover root weevil *Sitona lepidus* Gyllenhal [Coleptera: Curculioidae]

Pest status

Clover root weevil, an introduced species, was first detected in the North Island during the mid 1990s and has since spread throughout much of that island and to locations in the South Island. It is expected this pest will colonize pasture lands throughout New Zealand in time. Both adults and larvae feed on clover and cause a decline in clover content and pasture quality. The early larval stages attack the nitrogen-fixing root nodules and older larvae will attack the roots and stolons of white clover. Adults are foliage feeders and may destroy young seedlings. Adults may be found all year round but are most abundant in summer, and they actively disperse under hot dry conditions. Larvae may also be found throughout the year but are most abundant from late autumn to early spring. Moist summer conditions favour population survival and development, and there is likely to be several overlapping generations in many locations throughout New Zealand.

Role of insecticides

The research on this pest in New Zealand has not considered insecticides to any extent. Rather, the development of control options has focused on potential biological control agents (parasitoid, fungal pathogens) and pasture management strategies.

Only one insecticide has been registered for control of clover root weevil. Chlorpyrifos is targeted at adults as a foliar spray when pest populations in pastures are high, or for the protection of clover seedlings from adult feeding. Two applications 14 days apart are recommended.

Factors affecting efficacy

As with any foliar insecticide with contact action, applications must be timed with the peaks of pest occurrence for maximum effect. Thorough coverage of foliage is also essential. Given the high dispersive capabilities of adults detecting the peak emergence or invasions of adults into pastures could affect a farmer's ability to accurately time applications. The need for multiple applications to cover periods of adult abundance is a potential limitation of using insecticides for control of this pest.

The application of contact insecticides like chlorpyrifos which also have some residual persistence could limit the effectiveness of the parasitoid introduced for this pest. Most parasitoids are susceptible to organophosphate insecticides.

It is not likely there will an issue with resistance by clover root weevil to insecticides because of the very low use of insecticides against this pest.

Summary

Only one insecticide active ingredient is presently registered for control of clover root weevil adults in pasture. It is unlikely insecticides will play a significant role on the management of clover root weevil.

Table 11: Insecticides registered for clover root weevil (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Pasture							
	chlorpyrifos	Lorsban 750 WG Rampage Encaps	0.33 kg	0.25 kg	Apply at clover seedling emergence.	When pest pressure high and several generations occur, two applications of 167 grams/ha 14 days apart are recommended.	7 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

2.3.4 Grass grub *Costelytra zealandica* White [Coleoptera: Scarabaeidae]

Pest status

Grass grub, a native species, is widespread throughout New Zealand infesting improved ryegrass clover pastures as well as natural grasslands and forage crops drilled into pasture land. Larval stages feed on the roots of a wide range of plants and may cause widespread destruction especially in establishing crops and pastures. This species has commonly been regarded as one of the most important pests of pastures due to its persistence and potential for damage. There is one generation per year in most parts of New Zealand, although larval development may be delayed at lower latitudes and higher altitudes thereby requiring two years to complete a life cycle. Larval damage is most severe in autumn and early winter when third instar larvae are feeding closer to the soil surface. Larval densities in excess of $100/m^2$ commonly result in economic loss in establishing pastures. Feeding damage by adults is not significant in pasture, although they may defoliate emerging forage crop seedlings and leaves of other crops in spring during the adult flight period.

Role of insecticides

There is a long history of research into insecticides for control of grass grub in pastures and forage crops, and a wide range of organochlorine, organophosphate and other insecticides has been registered for this pest. The initial approach for using insecticides was broadcast application using liquid or granular formulations to provide year-long protection of pastures, especially when using organochlorine insecticides like DDT. With the advent of organophosphate insecticides, more strategic approaches to the use of insecticides were developed, e.g., protection of seedling crops and pasture by drilling insecticide with seed, spot treatment of infested areas, controlled release formulations. The discovery of pathogenic bacteria and other micro-organisms has more recently led to the development of microbial insecticides.

There is a relatively limited range of insecticides available at present which are either seed dressings or granular insecticides. Granular formulations can be applied with seed at pasture establishment, or broadcast on the surface of pastures or other infested areas. Liquid formulations are applied as a spray to the soil surface of pastures and crops. Some insecticides have systemic action (imidacloprid, clothianidin) and others systemic and contact action (phorate, terbufos), chlorpyrifos and diazinon only have contact action and rely on their residual properties in the soil around the root zone to provide protection from larval feeding. Seed dressing and granular insecticides generally provide sufficient protection for seedling establishment, while a controlled release formulation of chlorpyrifos claims to protect plants for up to several years.

A microbial formulation containing the bacterium *Serratia* sp can be direct-drilled into to pastures during autumn when late second instar to mid third instar larvae are feeding near the surface. Establishment of disease in the population can provide suppression of grass grub populations for several years.

Factors affecting efficacy

For seed dressings, insecticides should be applied using properly calibrated seed treatment machines. Calibration of seed drilling equipment is also required as seed dressings may alter seed sowing rate. Adequate soil moisture is required to allow seedling growth and uptake of seed dressing or granular insecticide.

For liquid or granular contact insecticides applied to the soil surface, sufficient rainfall must fall within a week of application, and soil moisture must be sufficient for movement of insecticide into the soil. Some soil types, e.g., clay or peaty may reduce the effectiveness of some organophosphate insecticides.

Some populations of grass grub have become resistant to organochlorine and organophosphate insecticides in the past. However, the distribution and status of resistance in grass grub populations is not well documented. Resistance in grass grub populations is only like to be exacerbated when applications of insecticide are made repeatedly over many years.

Summary

Contact and systemic insecticides can be used to protect establishing forage crops and pastures from larval damage during autumn. Granular and liquid formulations, either broadcast or direct drilled, may also be applied to protect established pastures. A granular formulation of a bacterial insecticide can provide long term suppression of grass grub populations. There is a risk some organophosphate insecticides could be withdrawn in the short to medium term.

Table 12: Insecticides registered for grass grub (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Pasture							
	chlorpyrifos	SusCon Green	15.0 kg	1.5 kg	Apply at establishment or when pasture is renovated.	Granules must be completely covered by soil	42 days
	diazinon	Diazinon 800 EC Diazinon 20 G	3 litres 11.0 kg	2.4 kg 2.2 kg	Apply when grubs are near the surface in early autumn	Rainfall needed after application. Use 5.5 kg/ha granules if direct drilled.	nil
	phorate	Thimet 20 G	5 .0 kg	1.0 kg	Apply in furrow at sowing.	Not very effective against grass grub when populations high.	42 days
	Serratia	Bioshield Grass Grub	30 kg		Apply sub-surface when grubs are actively feeding.	Granules may be direct drilled into established pasture or at pasture establishment	nil
Grass seed[2]							
	clothianidin	Poncho	Seed treatment		Apply to seed before drilling.	Applied only as a seed treatment.	42 days
	imidacloprid	Gaucho Sombero 600	580 ml/100 kg seed		Apply to seed before drilling.	Mix with sufficient water to ensure thorough coverage of seed.	42 days
	terbufos	Counter 20 G	3.0-4.0 kg	0.6-0.8 kg	Apply in furrow at sowing.	Use higher rate when ground has not been cultivated and fallowed for 6 weeks and when there is high pest pressure.	14 days
Forage crops							
cereal	clothianidin	Poncho	Seed treatment		Apply to seed before drilling.	Applied only as a seed treatment.	42 days
cereal	imidacloprid	Gaucho Sombero 600	580 ml/100 kg seed		Apply to seed before drilling.	Mix with sufficient water to ensure thorough coverage of seed.	42 days
cereal	terbufos	Counter 20 G	3.0-4.0 kg	0.6-0.8 kg	Apply in furrow at sowing.	Use higher rate when ground has not been cultivated and fallowed for 6 weeks and when there is high pest pressure.	42 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

[2] Grass seed here refers primarily to grass seed sown for pasture.

2.3.5 Sitona weevil *Sitona discoideus* Gyllenhal [Coleoptera: Curculionidae]

Pest status
Sitona weevil, an introduced species, is found throughout New Zealand and is more prevalent in the main lucerne growing areas in the North and South Islands of New Zealand. Both adults and larvae may cause damage to lucurne, the adults by defoliation and the larvae by destruction of root nodules and roots. Younger lucerne stands are more susceptible to sitona weevil, and larval populations decline as the stand ages and the roots become more extensive. Adults live for about a year and disperse from lucerne in summer to aestivation sites. Adults return to lucerne during autumn to lay eggs which continues to the following spring. Larval numbers peak in the soil during spring. There is one generation per year. Damage is localized and sporadic, and the establishment of a parasitoid has significantly reduced the impact of this pest.

Role of insecticides
Nowadays, it is likely insecticides play only a minor role in the management of sitona weevil. Prior to the establishment of an effective parasitoid, foliar sprays of insecticides were targeted at adults during autumn as they returned from summer aestivation sites. This reduced the adult population and subsequent egg laying, and thereby reduced larval populations.

Three insecticide active ingredients with contact action remain registered for sitona weevil for control of adults during the autumn flights.

Factors affecting efficacy
The effectiveness of contact insecticides applied as foliar sprays is very dependent on crop coverage. When the growth of lucerne stand is vigorous, the use of higher insecticide and water rates is recommended Experience suggests younger stands will benefit more from insecticide applications than older stands.

The strategy of targeting adults returning to lucerne stands from summer aestivation sites presents a challenge to farmers to determine when peak flights are occurring. Extended flight periods could require several applications at intervals to reduce the adult population sufficiently.

Disruption of parasitoids by insecticides is likely with the registered products, as they are highly effective contact insecticides with reasonable foliar persistence.

The likelihood of Sitona weevil developing resistance to insecticides is regarded as very low due to low insecticide selection pressure being placed on this pest.

Summary
There are three insecticide active ingredients registered for control of sitona weevil on lucerne. They are applied as sprays targeted at adults returning to lucerne stands following summer aestivation. There is a risk two organophosphate insecticides could be withdrawn in the short to medium term.

Table 13: Insecticides registered for Sitona weevil (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Forage crops							
lucerne	chlorpyrifos	Chlopyrifos EC Rampage Encaps	0.6-0.8 litres 1.2-1.6 litres	0.3-0.4 kg 0.3-0.4 kg	Apply to adults after flights cease and before egg laying.	Use higher rate on dense stands of Lucerne.	7 days
lucerne	deltamethrin	Decis Forte	0.25 litres	7 grams	Apply to adults after flights cease and before egg laying.		21 days
lucerne	fenitrothion	Caterkil 1000	0.6 litres	0.6 kg	Apply to adults after flights cease and before egg laying.		14 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

2.3.6 Tasmanian grass grub *Acrossidius tasmaniae* Hope [Coleoptera: Scarabaeidae]

Pest status

Tasmanian grass grub, an introduced species, is found at locations in both the North and South Islands of New Zealand especially in pastures on alluvial and other free-draining soils. Larvae cause damage by defoliating pasture plants in a manner similar to porina caterpillars. They emerge at night to collect foliage, animal dung and other organic matter which they take into their tunnels to feed on for the following 7-10 days. Third instar larvae are the most damaging stage appearing first in late autumn and feeding sporadically throughout the winter. Adult flights occur during mid to late summer, and there is one generation per year. Damage by Tasmanian grass grub is more severe in establishing pastures or those that have been weakened by drought stress.

Role of insecticides

Because of the sporadic occurrence of Tasmanian grass grub, periodic treatment of pasture with contact insecticides is the most appropriate control action to take when pasture damage becomes noticeable. Three contact insecticides have registrations for Tasmanian grass grub which are applied as spays at the first sign of grubs or damage in the autumn. Spot treatment of infested areas is likely to be all that is warranted unless the pest is widespread and the population densities are high. Withholding periods vary between 7-14 days, and this may be a factor to consider should it be necessary to return stock to treated pasture.

Factors affecting efficacy

The application of contact insecticides to control larval pests that emerge from the soil depend on having a good cover of insecticide on the plant and soil surfaces when the insects emerge to feed. Cold or frosty conditions will not be conducive to insect activity and, therefore, insecticide applications at these times should be avoided. It is also recommended to apply the higher recommended rate when late larval instars are present or when population densities are high. Harrowing with chain harrows before spraying to break open dung and expose larvae is also recommended.

There are no reported cases of resistance by Tasmanian grass grub to insecticides, and the risk of resistance development is very low due to low insecticide selection pressure being placed on this pest.

Summary

There are three insecticide active ingredients registered for control of Tasmanian grass grub on pasture. They are applied as sprays targeted at the larval stages as they emerge from their burrows to feed. There is a risk two organophosphate insecticides could be withdrawn in the short to medium term.

Table 14: Insecticides registered for Tasmanian grass grub (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Pasture							
	alpha-cypermethrin	Alpha-Scud	100-150 ml	10-15 grams	Apply at first appearance of grubs and damage in autumn.	Use higher rate when grubs are greater than 1 cm long.	7 days (grazing) 14 days for cut forage.
	chlorpyrifos	Chlorpyrifos 500EC	1.25-1.5 litres	0.625-0.75 kg	Apply at first sign of damage.	Harrow dung to expose larvae. Use higher rate when populations are high.	14 days
	fenitrothion	Caterkil 1000	0.9-1.2 litres	0.9-1.2 kg	Apply when damage occurs or infestation noticed.	Use higher rate for heavy infestations of larger grubs.	14 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

2.3.7 Weevils (unspecified species) [Coleoptera: Curculionidae]

Pest status

A range of native and introduced weevil species (other than those species mentioned) periodically attack pasture and forage crops. While weevils, especially adults, are reasonably easily recognized, the precise identity of species is more problematic for farmers, consultants, etc.

Unspecified weevil species are mentioned on several insecticide labels, especially for forage brassica crops. It is possible weevils attack seedling forage crops because they have emerged from the soil which was previously in pasture. Argentine stem weevil is sometimes implicated in this way. On seedling forage crops, damage by adult weevils can be significant and thus control of weevils by insecticide can be justified.

Role of insecticides

There are two broad approaches for protecting seedling forage brassicas from pests, viz., application of a granular formulation of a systemic insecticide, or application of a contact insecticide at or shortly after the emergence of seedlings. Drilling granular systemic insecticides (phorate, terbufos) with seed has the advantage of protection as soon as the seedling emerges as well as providing protection against other chewing and sucking pests, e.g., springtails and aphids. A contact insecticide (fenitrothion) applied at crop emergence has the advantage of applying an insecticide only when there is a demonstrated need. Both approaches are likely to be equally successful if applications are made according to label instructions.

Factors affecting efficacy

Other than adequate levels of soil moisture and an appropriate application rate for granular systemic insecticides, relatively little should affect the efficacy of these insecticides.

For a contact insecticide which is recommend to be applied between sowing and crop emergence, timing of application and post-application weather conditions may reduce efficacy.

There are no known cases of weevil resistance to insecticides in New Zealand, and the risk of resistance development is very low due to low insecticide selection pressure being placed on this pest.

Summary

Two systemic and one contact insecticide have registrations for unspecified weevil species on forage brassica crops. Seedling protection can be achieved by either drilling systemic granular insecticides with seed or applying a contact insecticide between sowing and crop emergence.

Table 15: Insecticides registered for weevils (unspecified species) (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Forage crops							
brassica	fenitrothion	Caterkil 1000	0.6 litres	0.6 kg	Apply between sowing and crop emergence.		14 days
brassica	phorate	Thimet 20G	5.0 kg	1.25 kg	Apply in furrow at sowing.		42 days
brassica	terbufos	Counter 20G	3.0 kg	0.6 kg	Apply in furrow at sowing.		42 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

2.3.8 Armyworm (various species) [Lepidoptera: Noctuidae]

Pest status

Various armyworm species including northern armyworm, *Mythimna separata* (Walker), southern armyworm *Persectania aversa* (Walker), and tropical armyworm *Spodoptera litura* (F.) attack pasture, graminaceous seed crops or maize at various localities in New Zealand. The distribution of the respective species varies, and their importance as pests varies with prevailing weather conditions. Although they may occur sporadically, they can be devastating when population densities are high. Caterpillars strip pasture plants of foliage, however, the specific plants species they attack varies between armyworm species. Caterpillars feed most actively during the evening under warm conditions. There is like to be several generations of each species per year, depending on temperature and the availability of food. Overlapping generations are likely later in the growing season.

Role of insecticides

Given the sporadic occurrence of armyworms and the rapidity at which damage can occur with high populations of caterpillars, insecticides have remained the most effective way of managing these pests on pasture and forage crops. Parasitic insects and other natural enemies likely contribute to the regulation of armyworm populations outside pasture and forage crops.

All insecticides registered for use against armyworms are contact insecticides belonging to organophosphate (chlorpyrifos, diazinon, methamidophos, trichlorfon), carbamate (carbaryl, methomyl) and pyrethroid (alpha-cypermethrin) chemical groups. The general recommendation is for applications of insecticide to be made on first appearance of the pest or damage with repeat applications as necessary. Aerial application is used on maize crops when crop growth limits ground application.

Only one insecticide (diazinon) is registered for use on grass seed crops against armyworms.

Factors affecting efficacy

The correct application rate and coverage are the key requirements to achieve effective control of caterpillar pests with contact insecticides. Higher water rates and insecticide rates are required for crops with dense canopies.

With armyworms being more active in the evenings under warm conditions, applications at these times will enhance control. Application intervals may vary with the insecticide and rate used and/or pest pressure.

Although cases of armyworm resistance to insecticides have not been documented in New Zealand, *Spodoptera litura* is reported to be resistant to many insecticides (ogranochlorines, organophosphates, carbamates and pyrtheroids) in other countries, and *Mythimna separata* has been reported resistant to several insecticides (pyrethroids) in China. These reports reflect the potential of these species to develop resistance to insecticides given sufficient selection pressure is applied to populations.

Summary

There is a range of organophosphate, carbamate and pyrethroid insecticides for control of armyworm species on pasture, graminaceous seed crops and forage crops. There is a risk four organophosphate and one carbamate insecticide could be withdrawn in the short to medium term. Potentially, withdrawal of organophosphate and carbamate insecticides could increase the risk of resistance selection in other insecticide classes, e.g., pyrethroids.

Table 16: Insecticides registered for armyworm (unspecified species) (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Pasture							
	chlorpyrifos	Chlorpyrifos EC	0.40 litres	0.2 kg	Apply on first appearance damage.		7 days
	diazinon	Diazinon 800 EC	0.8 litre	0.64 kg	Apply on first appearance damage.	Apply when insects actively feeding in morning or evening.	nil
	methomyl	Lannate L	1.5-2.0 litres		Apply on first appearance of pests.	Repeat applications may be necessary.	7 days
	trichlorfon	Triforon	1.8-2.4 litres	0.9-1.2 kg	Repeat applications may be necessary.	Apply during early evening under warm conditions.	5 days
Grass seed crops							
	trichlorfon	Triforon	1.8-2.4 litres	0.9-1.2 kg	Repeat applications may be necessary.	Apply during early evening under warm conditions.	5 days
Forage crops							
cereal	methomyl	Lannate L	1.5-2.0 litres		Apply on first appearance of pests.	Repeat applications may be necessary.	7 days
cereal	trichlorfon	Triforon	1.8-2.4 litres	0.9-1.2 kg	Repeat applications may be necessary.	Apply during early evening under warm conditions.	5 days
maize	alpha-cypermethrin	Alpha-Scud	0.15-0.20 litres	15-20 grams	Apply on first appearance of pests.	Use higher rate and 300-600 litres water/ha to ensure penetration.	14 days
maize	carbaryl	Sevin Flo	1.6-2.4 litres	0.6-1.2 kg		Apply in sufficient water to cover.	3 days
maize	chlorpyrifos	Lorsban 750 WG	0.26 kg	0.2 kg	Apply on first appearance of pests.		7 days
maize	methamidaphos	Tamaron	1.0 litre aerial application	0.6 kg		Thorough coverage and penetration of the crop canopy is essential.	3 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

2.3.9 Clover casebearer moth *Coleophora mayrella* (Hubner), *C. alcyonipenella* (Kollar) [Lepidoptera: Coleophoridae]

Pest status

Clover casebearers of two introduced species are found throughout New Zealand and are recognized pests of clover seed crops in Canterbury. Moths emerge in spring and females deposit eggs on clover florets. Larvae destroy developing seed and yield losses of up to 90% have been recorded. Seed crop management practices and activity by parasitoids may limit the impact of these pests.

Role of insecticides

Past research has demonstrated cost-effective management of clover casebearer is feasible in clover seed crops using short-lived or bee-safe insecticides which minimize harm to pollinating bees. Insecticide applications to clover seed crops are aimed at limiting the adult populations from laying eggs on the crop. Only two active ingredients have registration for use on clover seed crops when bees are present. Dichlorvos acts by contact and fumigant action and has a very short residual action. If applied in the evening when bees are not in the crop, residues will dissipate to a safe level by the following day. Tau-fluvalinate is regarded as bee-safe, but must also be applied when bees are not actively foraging in a crop. Once dried, the residues are considered relatively harmless to foraging bees.

Factors affecting efficacy

Insecticide applications to clover seed crops are aimed at limiting the adult populations laying eggs on the crop. Therefore application timing is critical. Monitoring moth populations with a sweep net can assist in determining when moths are entering crops. Applications should be made as moth numbers are peaking but before significant egg laying has occurred. A repeat application may necessary if moth flights are prolonged.

Summary

Two insecticide active ingredients are registered for control of clover casebearers on clover seed crops. There is a risk dichlorvos could be withdrawn in the short to medium term.

Table 17: Insecticides registered for clover casebearer moth (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Clover seed crops							
	dichlorvos	Divap Nuvos	130-190 ml 150-220 ml	0.15-0.22 kg 0.15-0.22 kg	Apply when moths are prevalent.	Repeat application after 7-10 days if moth flights continue.	1 day
	tau-fluvalinate	Mavrik Aquaflow	150 ml	0.63 kg	Apply when moths appear in the crop.		56 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

2.3.10 Corn earworm/tomato fruitworm *Helicoverpa armigera conferta* Walker [Lepidoptera: Noctuidae]

Pest status
Corn earworm, an introduced species, feeds on a wide range of host plants but causes most significant damage to maize and tomato. It may cause defoliation to maize for forage, but also damages developing silks and seeds of the cob. Although this pest is found in the South Island, it is likely that only maize growing areas in the north of the North Island will be affected by this pest. There are two to three generations per year depending on seasonal conditions.

Role of insecticides
Although pathogens and parasitoids may play some role in regulating corn earworm populations, the use of insecticides has been the main strategy to combat this pest. In common with other defoliating caterpillar species, contact insecticides are targeted at early instar caterpillars. Examples of organophosphate, carbamate and pyrethroid insecticides are registered for use against this pest. Aerial application may be used on maize crops at later stages of crop development.

Factors affecting efficacy
Achieving thorough cover with foliar applications is essential for control of corn earworm. Repeat applications may be necessary to cover the period young caterpillars are emerging from eggs. Delayed applications against later instars will normally require higher rates of application.

Heliothis species are renown world-wide for their capacity to develop resistance to insecticides. Although shifts in the tolerance to some pyrethroid insecticides have been indicated in New Zealand, widespread resistance has not yet occurred. A resistance management strategy is available in New Zealand for *Heliothis* (www.nzpps.org).

Summary
Seven insecticides with contact action are available for corn earworm control. There is a risk two organophosphate and one carbamate insecticide could be withdrawn in the short to medium term. Potentially, withdrawal of organophosphate and carbamate insecticides could increase the risk of resistance selection in other insecticide classes, e.g., pyrethroids.

Table 18: Insecticides registered for corn earworm (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Forage crops							
maize	alpha-cypermethrin	Alpha-Scud	0.15-0.20 litres	15-20 grams	Apply on first appearance of pests.	Use higher rate and 300-600 litres water/ha to ensure penetration.	14 days
maize	carbaryl	Sevin Flo	1.6-2.4 litres	0.6-1.2 kg		Apply in sufficient water to cover.	3 days
maize	chlorpyrifos	Lorsban 750 WG	0.26 kg	0.2 kg	Apply on first appearance of pests.		7 days
maize	deltamethrin	Decis Forte	0.36 litre	17 grams	Apply at first sign of damage in the cob tassels.	Repeat application 14-21 day intervals as required.	14 days
maize	es-fenvalerate	Sumi-Alpha	0.25 litre aerial application	12.5 grams	Apply on first appearance damage.		14 days
maize	methomyl	Lannate L	1.5-2.0 litres		Apply on first appearance of pests.	Repeat applications may be necessary.	7 days
maize	trichlorfon	Trifon	1.8-2.4 litres	0.9-1.2 kg	Apply at appearance of silks.	Repeat applications may be necessary.	14 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

2.3.11 Diamondback moth *Plutella xylostella* (L.) [Lepidoptera: Yponomeutidae]

Pest status

Diamondback moth, an introduced species, is found throughout New Zealand on both horticultural and forage brassicas. This pest is the most devastating pest of horticultural brassicas and is also capable of causing extensive damage on forage brassicas. Diamondback moth larvae are difficult to control because of their habit of concealing themselves between the young and developing leaves in the centre of a brassica plants, and their capacity to develop resistance to insecticides. Large populations may build up rapidly under favourable weather conditions, and there may be as many as six to seven generations per year. A number of parasitoids and pathogens attack diamondback moth with variable effects.

Role of insecticides

Pyrethroid and organophosphate insecticides with contact action are primarily used to control diamondback moth on forage brassicas. A microbial insecticide containing *Bacillus thuringiensis* was previously registered for use on forage brassics, but no product is this type is currently registered for use on these crops.

There is debate about the value of applying insecticides to control this pest on forage brassicas because the cosmetic quality of plants for animal consumption is of little consequence, compared with that on horticultural brassicas. The capacity for some forage brassicas, e.g., turnip, to compensate for pest damage is a further reason why insecticides may not be warranted. Young crops under severe attack from diamondback moth during hot summers will likely benefit most from insecticide protection, however.

Factors affecting efficacy

Early detection of the pest before significant numbers of caterpillars establish in the centre of plants is essential for effective control by insecticides. Lower rates may be used on younger caterpillars and younger crops, however, the rate should be increased with increasing crop size and pest density. Good spray coverage and penetration to the centre of plants is essential. The use of surfactants is recommended with most insecticides on brassica crops. Repeat applications may be needed when pest pressure is high.

Diamondback moth is notorious world-wide for its capacity to develop resistance to all major classes of insecticides. Resistance to some organophosphate and pyrethroid insecticides has been confirmed from New Zealand. It is likely resistance selection in this pest occurs on horticultural brassicas owing to the more intensive use of insecticides to maintain plant quality. However, diamondback moth is a mobile species and resistant individuals originating from horticultural brassicas could colonise forage brassicas. A resistance management strategy is available in New Zealand for diamondback moth (www.nzpps.org).

Summary

Eight insecticide active ingredients with contact action are registered for diamondback moth on forage brassicas. There is a risk two organophosphate insecticides could be withdrawn in the short to medium term. Potentially, withdrawal of organophosphate insecticides could increase the risk of resistance selection in other insecticide classes, e.g., pyrethroids. Farmers who are regularly spraying forage brassica crops for diamondback moth should follow the New Zealand resistance management strategy for this pest.

Table 19: Insecticides registered for diamondback moth (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1, 2]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period[3]
Forage crops							
brassica	deltamethrin	Decis Forte	0.36 litre	10 grams	Apply when caterpillars or damage is first noticed.	Repeat applications at 10-14 day intervals may be needed.	3 days*
brassica	diazinon	Dew 600	1.0 litre	0.6 kg	Apply when caterpillars or damage is first noticed.		nil
brassica	es-fenvalerate	Sumi- Alpha	0.375 litre	19 grams	Apply when caterpillars or damage is first noticed.		7 days*
brassica	lambda-cyhalothrin	Cyhella, Karate	40 ml	10 grams	Apply when caterpillars or damage is first noticed.		14 days
brassica	lambda-cyhalothrin/pirimicarb	Dovetail	1.0-1.25 litres	5-6 grams/100-125 grams	Apply when caterpillars or damage is first noticed.		14 days
brassica	maldison	Malathion 50 EC	3.0 litres	1.5 kg	Apply when caterpillars or damage is first noticed.		7 days
brassica	permethrin/pirimiphos methyl	Attack	0.75-1.0 litre	75-100 grams/0.36-0.47 kg	Apply when caterpillars or damage is first noticed.	Use lower rate on younger crops.	7 days
brassica	trichlorfon	Trifon	1.8-2.4 litres	0.9-1.2 kg	Apply when caterpillars or damage is first noticed.		14 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

[2] Diamondback moth occurs on both forage and horticultural brassicas. It is not clear from some insecticide labels that the recommendation applies to either or both types of brassica crops, therefore it is assumed that the recommendation would apply to both forage and horticultural brassicas.

[3] It is not clear from some labels that the withholding period applies to horticultural or forage brassica crops. In these cases, the withholding period listed is marked with an asterisk. Note that other pyrethroid insecticides require a 14 day withholding period for forage brassica crops.

2.3.12 Greasy cutworm *Agrotis ipsilon aneituma* Walker [Lepidoptera: Noctuidae]

Pest status

Greasy cutworm, an introduced species, is a sporadic pest of a range of field and vegetable crops. It occurs throughout New Zealand and is considered most damaging to young brassicas and seedling cereals, especially maize. Caterpillars which are mainly active at night cause damage by severing seedlings or young plants at or just below soil level. There are two to three generations per year depending on the locality and prevailing weather conditions. Native cutworms (*Melanchra* sp) may also occur and cause similar damage.

Role of insecticides

Given the sporadic occurrence of greasy cutworm, application of contact insecticides is the most appropriate control strategy. The use of insecticide bait (bran with trichlorfon) is an alternative approach to spraying. Organophosphate and pyrethroid insecticides are commonly applied as a spray directed towards the base of plants at the first signs of appearance of cutworms. Protection of maize seedling may also be achieved with a seed dressing of a systemic insecticide.

Factors affecting efficacy

Applying sufficient active ingredient towards the base of plants is the single most important factor affecting efficacy. Early recognition of the pest when caterpillars are smaller should allow lower application rates to be used, however, higher rates would be recommended with larger caterpillars. Repeat applications may be needed when pest pressure is high.

The risk of insecticide resistance developing in greasy cutworm is regarded to be low due to low insecticide selection pressure being placed on this pest.

Summary

A range of organophospate and pyrethroid active ingredients with contact action is registered for greasy cutworm on forage brassicas and maize. A systemic seed dressing is also registered for maize. There is a risk two organophosphate insecticides could be withdrawn in the short to medium term.

Table 20: Insecticides registered for greasy cutworm (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Forage crops							
brassica	lambda-cyhalothrin	Cyhella	40 ml	63 grams	Apply at first sign of pests.	Direct spray towards the base of plants.	14 days
brassica	trichlorfon	Trifon	2.4-3.6 litres	1.2-1.8 kg	Apply at first sign of pests.	Direct spray towards the base of plants. May also be mixed with bran and sugar as baits.	14 days
maize	alpha-cypermethrin	Alpha-Scud	0.15-0.20 litres	15-20 grams	Apply on first appearance of pests.	Use higher rate and 300-600 litres water/ha to ensure penetration.	14 days
maize	chlorpyrifos	Lorsban 50 EC	0.56 litre	0.28 kg	Apply on first appearance of pests.	Apply sufficient water for compete coverage.	14 days
maize	chlothianidin	Poncho	Seed treatment		Apply to seed before drilling.	Applied only as a seed treatment.	42 days
maize	deltamethrin	Decis Forte	0.45 litre	12.4 grams	Apply at first sign of pests.	Direct spray towards the base of plants.	14 days
maize	lambda-cyhalothrin	Cyhella	40 ml	63 grams	Apply at first sign of pests.	Direct spray towards the base of plants.	14 days
maize	methomyl	Lannate L	1.5-2.0 litres	0.3-0.4 kg	Apply at first sign of pests.	Direct spray towards the base of plants.	7 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

2.3.13 Porina *Wiseana* species [Lepidoptera: Hepialidae]

Pest status

Porina, a complex of native species, is found throughout much of New Zealand where improved pastures have been developed, but different species have different distributions. Porina is less common in the northern half of the North Island, and most research has been carried out on *Wiseana cervinata* in Canterbury. Porina caterpillars will attack grasses, clover and lucerne and cause extensive pasture defoliation in autumn and early winter when densities exceed 20-40 caterpillars per square metre. Caterpillars are at first surface dwelling and then construct vertical burrows in the soil from which they emerge to feed in the evening. The time pasture damage occurs varies with species and locality as a result of the different flight periods of adults of each species. There is normally one generation per year. The occurrence of porina can be sporadic with very high populations in some years and remain low in others. Monitoring caterpillar populations in pastures can help determine the need for control measures.

Role of insecticides

For sporadic and sometimes very damaging pests like porina, the use of insecticides is an appropriate pest management strategy. A range of contact insecticides and a growth regulator insecticide is available for control of porina in pastures.

To avoid extensive damage from late instar caterpillars early recognition of damage is essential. An application of an insecticide should be made when densities of caterpillars are in the range of 20-40 square metre, depending on the pasture type and growth.

Factors affecting efficacy

Applications of insecticide should be made to pasture under warm humid conditions that are favourable for porina caterpillar feeding. During cold and frosty conditions, caterpillars will not emerge from their burrows to feed and therefore contact with insecticide residues on plants or the soil surface will be minimal.

Insecticides will generally be more effective against earlier instars, and best results are usually achieved by application to short pasture immediately after rainfall. Higher rates of application will often be needed with larger caterpillars and when there are dense populations.

The risk of insecticide resistance developing in porina caterpillar is likely to be low, but the repeated use of diflubenzuron could increase this risk. Other lepidopteran species are known to develop resistance to diflubenzuron.

Summary

Four organophosphate insecticide active ingredients and one insect growth regulator are registered for control of porina on pastures. There is a risk four organophosphate insecticides could be withdrawn in the short to medium term, which would substantially limit insecticide options for control of this pest. Potentially, this could increase the risk of resistance development to diflubenzuron.

Table 21: Insecticides registered for porina caterpillar (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Pasture							
	chlorpyrifos	Chlorpyrifos 500EC Lorsban 50 EC	0.6-0.8 litre	0.3-0.4 kg	Apply when caterpillars are small and before extensive damage occurs.	Use higher rate when larger caterpillars are present. Do not apply under frosty conditions.	7 days
	diazinon	Diazinon 800 EC Diazinon 20 G	1.0-1.5 litres 5.5 kg	0.8-1.2 kg 1.1 kg	Apply when caterpillars are small and before extensive damage occurs.	Apply to closely grazed pastures. Best results occur under warm conditions.	nil
	diflubenzuron	Dimilin 2L Sniper	50 ml 50 ml	12 grams 12.5 grams	Apply when late surface-dwelling or early tunneling caterpillars are present.	Apply to short pasture preferably following rain.	7 days
	fenitrothion	Caterkil 1000	0.6-1.2 litres	0.6-1.2 kg	Apply when caterpillars are small and before extensive damage occurs	Use higher rate with larger caterpillars, dense infestations and dense pasture.	14 days
	trichlorfon	Trifon	2.1-2.4 litres	1.0-1.2 kg	Apply when caterpillars are small and before extensive damage occurs.	Apply during cloudy weather in late afternoon. Pastures should be closely grazed.	5 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

2.3.13 White butterfly *Pieris rapae* (L.) [Lepidoptera: Pieridae]

Pest status

White butterfly, an introduced species, is widespread throughout New Zealand on horticultural and forage brassica crops. Caterpillars defoliate brassica leaves often leaving them skeletonized by removing leaf tissue between the veins. White butterfly overwinters as pupae and there may be three to four generations per year depending on locality and weather conditions. This pest is generally more significant on horticultural brassicas where no damage is tolerated. White butterfly is often found in association with diamondback moth which is generally a more destructive and hard-to-control pest. Insecticides applied for diamondback moth will control white butterfly. A number of parasitoids attack larvae and pupae of white butterfly and may provide some suppression of this pest in forage brassica crops.

Role of insecticides

Pyrethroid and organophosphate contact insecticides provide adequate control of white butterfly, should damage to young plants be considered serious enough to warrant spraying.

There is debate about the value of applying insecticides to control this pest on forage brassicas because the cosmetic quality of plants for animal consumption is of little consequence, compared with that on horticultural brassicas. The capacity for some forage brassicas, e.g., turnip, to compensate for pest damage is a further reason why insecticides may not be warranted. Young crops under severe attack from white butterfly during hot summers will likely benefit most from insecticide application, however.

Factors affecting efficacy

Detecting the onset of a white butterfly infestation should not be too difficult if adult butterflies are seen on the crop. Eggs and young caterpillars are quite visible to the naked eye, and spraying is recommended when caterpillars or damage is first noticed.

White butterfly caterpillars are often found feeding on the undersides of outer leaves, and so spray coverage on those surfaces is essential.

Higher rates of application are recommended if there are larger caterpillars present in the crop, and repeat applications at 10-14 day intervals may be needed when pest pressure is high.

Summary

Four pyrethroid and two organophosphate contact insecticides are available to control white butterfly on forage brassica crops. There is a risk one organophosphate insecticides could be withdrawn in the short to medium term.

ADDED NOTE: Great white butterfly *Pieris brassicae,* has recently been reported in New Zealand (http://www.biosecurity.govt.nz/files/pests/great-white-cabbage-butterfly-fact-sheet.pdf, accessed 19 July 2010). This pest causes similar damage to *P. rapae* and could become an added threat to forage and horticultural brassica crops prompting the application of insecticides.

Table 22: Insecticides registered for white butterfly (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1,2]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period[3]
Forage crops							
brassica	deltamethrin	Decis Forte	0.36 litre	10 grams	Apply when caterpillars or damage is first noticed.	Repeat applications at 10-14 day intervals may be needed.	3 days*
brassica	es-fenvalerate	Sumi- Alpha	0.375 litre	19 grams	Apply when caterpillars or damage is first noticed.		7 days*
brassica	lambda-cyhalothrin	Cyhella, Karate	40 ml	10 grams	Apply when caterpillars or damage is first noticed.		14 days
brassica	lambda-cyhalothrin/pirimicarb	Dovetail	1.0-1.25 litres	5-6 grams/100-125 grams	Apply when caterpillars or damage is first noticed.		14 days
brassica	maldison	Malathion 50 EC	3.0 litres	1.5 kg	Apply when caterpillars or damage is first noticed.		7 days
brassica	permethrin/pirimiphos methyl	Attack	0.5-1.0 litre	12.5-25 grams/0.36-0.47 kg	Apply when caterpillars or damage is first noticed.	Use lower rate on younger crops.	7 days
brassica	trichlorfon	Trifon	1.8-2.4 litres	0.9-1.2 kg	Apply when caterpillars or damage is first noticed.		14 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

[2] White butterfly occurs on both forage and horticultural brassicas. It is not clear from insecticide labels that the recommendation applies to either or both types of brassica crops, therefore it is assumed that the recommendation would apply to both forage and horticultural brassicas.

[3] It is not clear from some labels that the withholding period applies to horticultural or forage brassica crops. In these cases, the withholding period listed is marked with an asterisk. Note that other pyrethroid insecticides require a 14 day withholding period for forage brassica crops

2.3.14 Aphids (numerous species) [Hemiptera: Aphididae]

Pest status

Aphids, mostly introduced species, are common pests on most crops and they are most troublesome on establishing seedlings during spring and autumn when the flights of many aphid species occur. Each crop is generally infested by several aphid species, one or two of which dominate and cause the most damage. Because most pest aphid species reproduce asexually throughout the year, populations of aphids can build up rapidly during favourable weather conditions. High numbers of aphids on seedling plants can result in wilting and loss of plants. Some aphids are vectors of plant viruses which can severely affect plant growth. Other aphids inject 'salivary toxins' which may have lasting impacts perennial crops like lucerne. Aphids pass through multiple generations per year, and have dispersal capabilities which enable to them to exploit new crops as soon as they emerge. Pastures are generally less affected by aphids, although root aphids are common but their impact on plant productivity is less well understood. The widespread occurrence, rapid reproduction and dispersal of aphids coupled with their capacity to transmit plant virus diseases make them serious pests in many situations.

Role of insecticides

Because of the rapid invasion and build up of aphid populations, insecticides have been a key method of control for most pest species. There are two key strategies for management of aphids on crop seedlings, viz., protecting seedlings pre-emergence with systemic seed dressings or granular systemic insecticides drilled at sowing, or, post-emergence application of foliar applied insecticides with contact, systemic and/or fumigant action. Seed dressings or granular systemic insecticides have the advantage of 'built in' protection as the seedling emerges, while post-emergence applications have the advantage of applying insecticide on the basis of need. Foliar applied insecticides, especially if they have contact and/or fumigant action, may need to be re-applied at intervals to protect new growth.

Aphids may periodically become pests of clover and brassica seed crops requiring the application of insecticides that will not be harmful to pollinating insects. Only two active ingredients have registration for use on clover seed crops when bees are present. Dichlorvos acts by contact and fumigant action and has a very short residual action. When applied in the evening when bees are not in the crop, residues will dissipate to a safe level by the following day. Tau-fluvalinate is regarded as bee-safe, but must also be applied when bees are not actively foraging in a crop. Once dried, the residues are considered relatively harmless to foraging bees.

Factors affecting efficacy

For seed dressings, insecticides should be applied using properly calibrated seed treatment machines. Calibration of seed drilling equipment is also required as seed dressings may alter seed sowing rate. Adequate soil moisture is required to allow seedling growth and uptake of seed dressing or granular insecticide.

Crops sprayed with contact insecticides require thorough coverage and penetration of spray into the growing points of plants, and repeat applications may be needed if reinvasion of aphids occurs.

One species, green peach aphid (*Myzus persicae*), a polyphagous species found on a wide range of hosts including brassicas, cereals and white clover, is resistant to various organophosphate, carbamate and pyethroid insecticides. A resistance management strategy has been developed for green peach aphid in New Zealand (www.nzpps.org). It is more likely resistant populations will be found on horticultural crops, however, the dispersive capability of this pest does not preclude resistant aphids moving to forage or seed crops.

Summary

There are two pyrethroid, eight organophosphate, one carbamate and two neonicotinoid insecticides registered for aphid control brassica and cereal forage crops. There two pyrethroid insecticides registered for aphid control on white clover seed crops. There is a risk four organophosphate insecticides could be withdrawn in the short to medium term.

Table 23: Insecticides registered for aphids (all species) (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Clover seed crops							
	lambda-cyhalothrin	Karate	40 ml	10 grams	Apply at first flower initiation and 10-14 days later if needed.		70 days
	tau-fluvalinate	Mavrik Aquaflo	0.15 litre	36 grams	Apply at first signs of aphids		56 days
Forage crops							
brassica	chlorpyrifos	Lorsban 50 EC	0.28-0.40 litre	0.14-0.20 kg	Apply at first signs of aphids.		7 days
brassica	dichlorvos	Nuvos, Divap	0.35-0.75 litre	0.35-0.75 kg			1 day
brassica	dimethoate	Rogor E	0.8-1.0 litres	0.32-0.4 kg	Apply at first signs of aphids.	Repeat applications may be necessary if reinvasions occur.	7 days
brassica	fenitrothion	Caterkil 1000	0.6 litre	0.6 kg	Apply between sowing and crop emergence.		14 days
brassica	imidacloprid	Gaucho Sombero 600	12-24 ml/kg seed		Apply to seed before drilling.	Mix with sufficient water to ensure thorough coverage of seed.	42 days
brassica	lambda-cyhalothrin/pirimicarb	Dovetail	1.0-1.25 litres	5-6 grams/100-125 grams	Apply before pests build up.		14 days
brassica	phorate	Thimet 20G	5.0 kg	1.25 kg	Apply in furrow at sowing.		42 days
brassica	maldison	Malathion 50 EC	3.0 litres	1.5 kg	Apply at first signs of aphids.		7 days
brassica	pirimicarb	Pirimor 50	0.20-0.25 kg	0.1-0.13 kg	Apply at first signs of aphids.	Apply lower rate to sparse crops.	7 days
brassica	terbufos	Counter 20 G	3.0 kg	0.6 kg	Apply at sowing.		42 days
brassica	thiamethoxam	Cruiser 600 FS	Seed treatment		Apply to seed before drilling.	Applied only as a seed treatment.	42 days
cereals	chlorpyrifos	Lorsban 50 EC	0.28-0.40 litre	0.14-0.20 kg	Apply at first signs of aphids.		7 days
cereals	diazinon	Dew 600	1.0 litre	0.6 kg			14 days
cereals	dichlorvos	Nuvos, Divap	0.35-0.75 litre	0.35-0.75 kg			1 day
cereals	imidacloprid	Gaucho Sombero 600	580 ml/100 kg seed		Apply to seed before drilling.	Mix with sufficient water to ensure thorough coverage of seed.	42 days
cereals	lambda-cyhalothrin	Karate	20-40 ml	5-10 grams			
cereals	pirimicarb	Pirimor 50	0.20-0.25 kg	0.1-0.13 kg	Apply at first signs of aphids.	Apply lower rate to sparse crops.	7 days

Table 21 continued on next page………….

Table 24 continued: Insecticides registered for aphids (all species) (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
lucerne	chlorpyrifos	Lorsban 50 EC	0.28-0.44 litre	0.14-0.22 kg	Apply at first appearance of aphids.		7 days
lucerne	deltamethrin	Decis Forte	0.23 litre	6.2 grams	Apply immediately after cutting if aphids appear on new growth.	Repeat applications may be necessary.	21 days
lucerne	dimethoate	Rogor E	0.3-0.5 litres	0.12-0.2 kg	Apply at first signs of aphids.	Repeat applications may be necessary if reinvasions occur.	7 days
lucerne	phorate	Thimet 20G	5.0 kg	1.25 kg	Apply in furrow at sowing.		42 days
lucerne	pirimicarb	Pirimor 50	0.20-0.25 kg	0.1-0.13 kg	Apply at first signs of aphids.	Apply lower rate to sparse crops.	7 days
maize	dimethoate	Rogor E	0.7 litres	0.28 kg	Apply at first signs of aphids.	Repeat applications may be necessary if reinvasions occur.	7 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

2.3.15 Green vegetable bug *Nezara viridula* (L.) [Hemiptera: Pentatomidae]

Pest status

Green vegetable bug, an introduced species, is a pest of numerous vegetable crops, and periodically migrates into maize crops where it feeds on developing kernels. It is a more significant pest of sweet corn where there is a very low threshold for damage to kernels. Brown shield bug, *Dictyotus caenosus*, is sometimes found on cereal, lucerne and brassica crops but populations are seldom large enough to warrant control.

Role of insecticides

Systemic insecticide applied as foliar sprays effectively manage shield bug pests.

Factors affecting efficacy

Sufficient coverage penetration into the crop canopy is essential.

A strategy developed for sweet corn whereby only the margins of a crop are sprayed could be adopted for maize. This approach works as green vegetable bug disperses from nearby vegetation to the margins of crops and progressively moves into a crop.

Summary

Only one systemic organophosphate insecticide is registered for control of green vegetable bug on maize. There is a risk this insecticide could be withdrawn in the short to medium term.

Table 25: Insecticides registered for green vegetable bug (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Forage crops							
maize	methamidaphos	Tamaron	1.0 litre aerial application	0.6 kg		Thorough coverage and penetration of the crop canopy is essential.	3 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

2.3.16 Wheat bug *Nysius huttoni* White [Hemiptera: Lygaeidae]

Pest status

Wheat bugs, and other locally-occurring lygaeid bugs, are periodically found on clover, brassica, cereal and several horticultural crops. Wheat bug is found throughout New Zealand, preferring open vegetation where the sunlight reaches the soil surface. Damage to seedling brassicas is reputed to occur through wheat bug piercing the developing stems at ground level causing a weakness or 'waist' at this point which may result in the stem breaking. Wheat bugs are very active under hot sunny conditions and readily disperse from adjacent areas of vegetation. There are three to four generations per year, however, high populations of wheat bug would be required on forage brassica seedlings to warrant control measures.

Role of insecticides

Controlling wheat bug on forage brassica seedlings is similar to the approach for aphid control. Pre-emergence use of systemic insecticide seed dressings, systemic granular insecticide drilled at sowing or, the application of a contact insecticide after drilling but before crop emergence, is recommended.

More established crops would not likely warrant the application of insecticides for control of wheat bug.

Factors affecting efficacy

Recognizing the invasion of wheat bug into forage brassica is the greatest challenge for farmers, therefore either a seed dressing or applying a granular insecticide provides 'insurance' protection against several sucking insect pests. When the risk of pest invasion is considered to be low, then application of an insecticide can be delayed until pests are observed. Warm sunny conditions are conducive to the spread of wheat bug.

Summary

There are three organophosphate insecticides, a neonicotinoid insecticide and a combination pyrethroid/organophosphate product available for wheat bug control on forage brassica crops. There is a risk two organophosphate insecticides could be withdrawn in the short to medium term.

Table 26: Insecticides registered for wheat bug (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Forage crops							
brassica	chlorpyrifos	Chlorpyrifos 500 EC Rampage Encaps	1.2 litres 2.4 litres	0.6 kg 0.6 kg	Apply when pest seen feeding on seedlings after emergence.		7 days
brassica	fenitrothion	Caterkil 1000	0.6 litre	0.6 kg	Apply between sowing and crop emergence.		14 days
brassica	imidacloprid	Gaucho Sombero 600	12-24 ml/kg seed		Apply to seed before drilling.	Mix with sufficient water to ensure thorough coverage of seed.	42 days
brassica	permethrin/pirimiphos methyl	Attack	0.5-1.0 litre	12.5-25 grams/0.36-0.47 kg	Apply when pest or damage is first noticed.	Use lower rate on younger crops.	7 days
brassica	phorate	Thimet 20G	5.0 kg	1.25 kg	Apply in furrow at sowing.		42 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

2.3.17 Mirids (several species) [Hemiptera: Miridae]

Pest status

Mirids are ubiquitous insects found on a variety of agricultural and horticultural crops throughout New Zealand. Two introduced species, Australian crop mirid *Sidnia kinbergi* Stal and potato mirid *Calocoris norvegicus* (Gmelin) are found in white clover seed crops in Canterbury. Both species are considered capable of causing damage to developing white clover seed, although local research has suggested potato mirid may be the more important of the two species. Economic benefits have been indicated following the application of insecticide for control of mirids and other sucking pests in white clover seed crops.

Role of insecticides

Only one pyrethroid insecticide has a registration for use against mirids in white clover seed crops. Lamda-cyholthrin reputedly has repellent and anti-feeding effects against insects and it has been suggested these properties reduce the colonization of white clover flowers by potato mirid nymphs and adults.

Lambda-cyhalothrin is relatively safe to bees when applied during the early morning or late evening when foraging bees are absent from the crop. Dried spray residues in treated crops may reduce honey bee foraging for two to three days.

Factors affecting efficacy

Good crop coverage in at least 200 litres water per hectare at first flower initiation is required for effective control of mirids. A repeat application after 10-14 days may be needed if mirids are still invading the crop.

Spraying the crop margins has been shown to be an effective strategy for minimizing infestations of potato mirids in white clover seed crops.

Summary

One pyrethroid insecticide is registered form mirid control in white clover seed crops.

Table 27: Insecticides registered for mirids (species unspecified) (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Clover seed crops							
	lambda-cyhalothrin	Karate	40 ml	10 grams	Apply at first flower initiation, and repeat at 10-14 days if necessary.		70 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

2.3.18 Australian soldier fly *Inopus rubriceps* (Macquart) [Diptera: Stratiomyidae]

Pest status

Australian soldier fly, an introduced species confined largely to northern New Zealand, is sporadically found in pastures but is more significant pest of maize seedlings. Larvae feed on the roots of grasses and cereals and when sufficient numbers are present will result in loss of plant vigour and death. Populations of several thousand larvae per square metre cause noticeable pasture damage, however, populations of 500 larvae per square metre will cause economic loss to maize seedlings if not protected by insecticide. The spread of this pest is slow and one life cycle may take up to 18 months to complete. Maize seedlings are at most risk if crops are drilled into previously infested pasture.

Role of insecticides

Although historical research showed it was possible to reduce Australian soldier fly populations in pasture following insecticide application, no insecticides are currently registered for control of this pest in pastures.

One insecticide (phorate) is currently registered for protection of maize seedlings, and is applied as a granule at sowing.

Factors affecting efficacy

For maize, phorate granules should be applied in a band above the seed and incorporated into the top two centimeters of soil to avoid contact with the seed.

Summary

One organophosphate insecticide is registered for control of Australian soldier fly in seedling maize.

Table 28: Insecticides registered for Australian soldier fly (species unspecified) (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Forage crops							
maize	phorate	Thimet 20G	7.5-10 kg	1.5-2.0 kg	Apply as a band application at sowing		42 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

2.3.19 Brassica leaf miner *Scaptomyza flava* (Fallen) [Diptera: Drosophilidae]

Pest status

Leaf mines on brassicas are likely to be caused by the introduced species *Scaptomyza flava,* which is found widely on horticultural and forage brassicas throughout New Zealand. It has also been collected from a range of horticultural crops. Larvae burrow within leaf tissue causing extensive mining and in the case of extensive damage premature leaf senescence. Relatively little is known of the biology and life cycle of this pest in New Zealand.

Role of insecticides

Although a range of insecticides has been tested for control of this pest on vegetable and forage brassicas, only one product (a combination of permethrin and pirimiphos methyl) is registered for use on forage brassicas. This product has contact and fumigant action and likely prevents populations establishing on treated leaves.

Factors affecting efficacy

It is recommended insecticide is applied at first appearance of the pest and thereafter at 2-3 week intervals, as necessary. A lower rate is recommended for younger crops, and the higher rate at crop canopy closure.

Summary

Only one combination pyrethroid/organophosphate product is registered for control of leaf miner on forage brassica.

Table 29: Insecticides registered for brassica leaf miner (species unspecified) (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Forage crops							
brassica	permethrin/pirimiphos methyl	Attack	0.5-1.0 litre	12.5-25 grams/0.36-0.47 kg	Apply when pest or damage is first noticed.	Use lower rate on younger crops.	7 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

2.3.20 Black field cricket *Teleogryllus commodus* (Walker) [Orthoptera: Gryllidae]

Pest status

Black field cricket is found in grassland areas throughout the North Island and some coastal regions of the South Island, although it is normally only a problem in pastures in the northern parts of the North Island. Grass plants may be completely defoliated to ground level, and seeds and seedlings are also prone to be attacked. Black field cricket adults and nymphs occupy cracks in the soil, and populations thrive under hot dry conditions. Females lay eggs in autumn which overwinter and hatch in spring. Nymphs develop through summer to produce adults in late summer. There is one generation per year, and densities greater than 10 crickets per square metre are damaging to pasture in hot dry summers. Newly-sown ryegrass is susceptible to attack particularly in the first year of establishment.

Role of insecticides

The most effective strategy for cricket control relies on applying a contact and stomach poisoning insecticide (maldison) on bran bait or wheat seed which is broadcast on the pasture surface in cricket infested areas. Aerial application has been used in extensive bait application programmes in the past.

A cricket flushing techniques can be used to estimate cricket populations in cracks the soil to determine whether it is economical to apply insecticide baits.

Factors affecting efficacy

Extensive field experiments in the past have indicated 10 kg bait per hectare was as effective as 20 kg bait per hectare. Bait applied in swaths of six metres with six metres left untreated between swaths gave control equivalent to broadcast application over the whole pasture.

Best results are achieved when applications of bait are targeted at young nymphs in January, and when applications are made following rainfall.

Baits must be dyed green to prevent birds consuming baits.

Summary

Maldison applied with bait is an effective method of black field cricket control in pastures.

Table 30: Insecticides registered for black field cricket (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Pasture							
	maldison	Malathion 50 EC	0.3 litre	0.15 kg	Soak 11 kg wheat in 0.3 litre maldison and water overnight. Allow to dry and apply bait when crickets first appear.	Treated seed must be dyed green to prevent it being eaten by birds.	7 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

2.3.21 Thrips (unspecified species) [Thysanoptera: Thripidae)

Pest status

A range of mostly introduced species can be found on many crops and pasture plants. The impact of most of those species is unknown, and thus the need to control them using insecticides cannot be reliably determined. Thrips adults and nymphs puncture leaf, flower and other tissue of plants causing a silvering, distortion and dessication.

Although thrips are ubiquitous in the agricultural landscape, few species are considered important pests of pasture and forage crops. Thrips on flowering seed crops may cause flower and seed damage, and thrips on seedling crops may warrant control.

Role of insecticides

Thrips are relatively easy to control with contact insecticides although some species in other countries have developed resistance to insecticides following repeated use.

Only one insecticide, lambda-cyhalothrin, is registered for control of thrips (unspecified species) on white clover seed crops.

Lambda-cyhalothrin is relatively safe to bees when applied during the early morning or late evening when foraging bees are absent from the crop. Dried spray residues in treated crops may reduce honey bee foraging for two to three days.

Factors affecting efficacy

Ideally, thrips should be controlled before populations become too established in a crop. However, given the extensive dispersal periods of many thrips, repeat applications of insecticides may be needed for complete protection.

Summary

One pyrethroid is registered for control of thrips on white clover seed crops.

Table 31: Insecticides registered for thrips (species unspecified) (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Clover seed crops							
	lambda-cyhalothrin	Karate	40 ml	10 grams	Apply at first flower initiation, and repeat at 10-14 days if necessary.		70 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

2.3.22 Springtails (several species) [Collembola: Sminthuridae]

Pest status
Springtails are common and sometimes serious pest of pastures and forage brassica crops in New Zealand. Clover flea (syn. lucerne flea) *Sminthuris viridis* L. is found throughout New Zealand and commonly attacks white clover, its preferred host. Pasture damage peaks in spring and autumn, however, the activity of clover flea declines in winter. Clover flea aestivates as eggs in hot summers.

Several *Bourletiella* springtail species attack cultivated plants, but *B. hortensis* (Fitch) is the most common species attacking brassica seedlings and is found throughout New Zealand. Damage to seedlings may occur as soon as the cotyledons emerge from the seed. Damage to seedlings appears as notches on the margins or small holes in the leaves.

The severity of springtail damage depends on the size of populations feeding on clovers or seedling brassicas.

Role of insecticides
Contact insecticides targeted a foliage on which springtails are feeding will generally provide effective control of these pests. Early detection is important to prevent build up of large damaging populations. For protection of clover in pasture, application of an insecticide when 10-20% of leaflets are showing damage is recommended. Applications targeting juvenile stages in late autumn are most effective.

For protection of forage brassica seedlings systemic insecticides can be applied as a seed dressing or as a granular insecticide at drilling. Alternatively, a contact insecticide spray could be applied after drilling and before crop emergence, or a systemic insecticide spray applied at the first sign springtails on seedlings.

Factors affecting efficacy
For seed dressings, insecticides should be applied using properly calibrated seed treatment machines. Calibration of seed drilling equipment is also required as seed dressings may alter seed sowing rate. Adequate soil moisture is required to allow seedling growth and uptake of seed dressing or granular insecticide.

Repeat applications of foliar-applied insecticides may be needed if springtail populations persist.

Summary
Two organophosphate insecticides and an insect growth regulator are registered for control of springtails in pasture. Five organophosphate, three neonicotinoids and one carbamate insecticide are registered for control of springtails on forage brassica crops. There is a risk four organophosphate insecticides could be withdrawn in the short to medium term.

Table 32: Insecticides registered for springtails (species unspecified) (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Pasture							
	chlorpyrifos	Chlorpyrifos 750 WG Rampage Encaps	0.133 kg 0.4 litre	0.1 kg 0.1 kg	Apply when 10-20% clover leaflets show damage.	Application ideally made late autumn-early winter when juveniles are predominant.	7 days
	diazinon	Diazinon 800 EC	0.35 litre	0.28 kg	Apply when pest first appears. Repeat at 4 weekly intervals if needed.		nil
	diflubenzuron	Dimilin 2L Sniper	50 ml 50 ml	12 grams 12.5 grams	Apply at first sign of pest.	Application ideally made late autumn-early winter when juveniles are predominant.	7 days
Forage crops							
brassica	chlorpyrifos	Rampage Encaps	0.4 litre	0.1 kg	Apply 1-2 days before crop emergence or as damage is noticed.		7 days
brassica	clothianidin	Poncho	Seed treatment		Apply to seed before drilling.	Applied only as a seed treatment.	42 days
brassica	dimethoate	Rogor E	0.8-1.0 litre	0.32-0.4 kg	Apply at first sign of pest.		7 days
brassica	fenitrothion	Caterkil 1000	0.6 litre	0.6 kg	Apply between sowing and crop emergence.		14 days
brassica	furathiocarb	Promax 400CS	12.5 ml/kg seed		Apply as a seed dressing.	Applied only as a seed treatment.	42 days
brassica	imidacloprid	Gaucho Sombrero 600	12-24 ml/kg seed		Apply as a seed dressing.		42 days
brassica	phorate	Thimet 20 G	5.0 kg	1.0 kg	Apply in furrow at sowing		42 days
brassica	terbufos	Counter 20 G	3.0 kg	0.6 kg	Apply at sowing.		42 days
brassica	thiamethoxam	Cruiser 600 FS	Seed treatment		Apply to seed before drilling.	Applied only as a seed treatment.	42 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

2.3.23 Redlegged earth mite *Halotydeus destructor* (Tucker) [Acari:Penthaleidae]

Pest status

Redlegged earth mite, an introduced species, is largely confined to eastern districts of the North Island especially Bay of Plenty, Hawke's Bay and Manawatu. It is not regarded a major pest of pastures in New Zealand, as it is in parts of Australia and South Africa. Little is known of the pest status of redlegged earth mite in New Zealand, however, it prefers to feed on subterranean clover, white clover, and medics. Seedling plants are at most risk from damage by redlegged earth mite where they feed on the upper surfaces of cotyledons by puncturing the surface cells. Subterranean clover appears more resistant than white clover, and there is variation in the susceptibility between cultivars of both clover species.

Role of insecticides

Spraying for control of redlegged earth mite is most likely to be restricted to sporadic and localized outbreaks on seedling legumes. Applications are recommended when leaves were showing blotch symptoms of mite feeding damage.

Factors affecting efficacy

Good spray coverage with contact insecticides is essential. Best effects would be achieved under warm conditions when mites are active in foliage.

Resistance by redlegged earth mite to synthetic pyrethroids as been detected in Australia.

Summary

One pyrethroid insecticide (alpha-cypermethrin) is registered for control of redlegged earth mite. There is a risk of resistance development to pyrethroid insecticides with repeated applications of chemicals from this class.

Table 33: Insecticides registered for red-legged earth mite (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Pasture							
	alpha-cypermethrin	Alpha-Scud	50 ml	5 grams	Apply when mite damage shown as leaf bleaching is noted, especially on legumes.		7 days (grazing) 14 days for cut forage.

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

2.3.24 Plant parasitic nematodes (various species)

Pest status

The major parasitic nematodes of pasture plants are the sedentary endoparasites *Heterodera trifolii* (clover cyst nematode) and *Meloidogyne* spp (root knot nematodes). Other nematodes e.g., *Pratylenchus* spp. (lesion nematodes) also occur on ryegrass and white clover. Separate races of stem nematode *Ditylenchus dipsaci* occur on white clover, red clover and lucerne. The pest status of nematodes in pastures and other crops is less well understood than for many insect pests. Plant parasitic nematodes are generally difficult to control soil unless fumigation or high doses of nematicidal chemicals are used. The key strategy for control of nematodes in pasture and forage crops has been to select nematode resistant cultivars. Cultural techniques and pasture rotations may also be valuable in reducing nematode populations in pastoral land. Chemical control is not regarded a viable option in most circumstances.

Role of nematicides

Only two products a registered for use against nematodes in clover and lucerne. For clover, a seed dressing (furathiocarb) can be applied to protect clover seedlings when pasture is being drilled back into nematode infested land (which is common from run-out pasture). For lucerne infested with stem nematode, spot treatment (fenamiphos) of infested areas in autumn or spring is suggested. Both nematicides possess systemic action.

Furathiocarb also possesses insecticidal action and is registered for use against springtails in forage brassicas and argentine stem weevil in grass and maize.

Factors affecting efficacy

For seed dressings, nematicides should be applied using properly calibrated seed treatment machines. Calibration of seed drilling equipment is also required as seed dressings may alter seed sowing rate. Adequate soil moisture is required to allow seedling growth and uptake of seed dressing or granular nematicide.

For spot treatment of lucerne, nematicide must be applied in at least 200-300 litres water per hectare to ensure good coverage.

Summary

Two nematicidal products are registered for use against plant parasitic nematodes in clover and lucerne. The use of these products would generally be limited to situations where nematodes were shown to be causing significant crop loss.

Table 34: Insecticides registered for plant parasitic nematodes (Novachem Manual, web version 2010).

Use area	Active ingredient (a.i.)	Products[1]	Rate per hectare	a.i. per hectare	Timing	Comments	W/h period
Clover crops							
	furathiocarb	Promax 400CS	50 ml/kg seed		Apply as a seed dressing.		42 days
Forage crops							
lucerne	fenamiphos	Nemacur Nematak 400	22-25 litres in 200 300 litres water		Applied as a spot treatment to nematode infested areas.	Applications best made in autumn or spring.	90 days

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on insecticide products refer to Table 5 or the New Zealand Novachem Agrichemical Manual.

2.4 Review of insecticide registrations in New Zealand

At any time, the Environmental Risk Management Authority (ERMA) of New Zealand can carry out reassessments of substances for which there is evidence that risks might not be effectively managed by the existing controls. This is consistent with the Hazardous Substances and New Organisms (HSNO) Act 1996 that is intended to protect the environment and health and safety of people and communities by preventing or managing the adverse effects of hazardous substances.

Reassessments of hazardous substances can be initiated by third parties, or by the Chief Executive of ERMA New Zealand. The Chief Executive maintains a short list of priority substances (Chief Executive Initiated Reassessment, CEIR, list) from which substances are selected for review (http://www.ermanz.govt.nz/hs/reassessment/ceo.html). At present, there are 20 substances (including insecticides, fungicides, herbicides and other substances) on the list including 12 insecticides that have past or current registrations for use on pasture and forage crops (Table).

Table 35: Environmental Risk Management Authority pesticide re-assessment list for insecticides that have had registrations for use on pastures or forage crops (as at July 2010).

Active ingredient	Chemical group	Review
acephate	organophosphate	Review underway
azinphos-methyl	organophosphate	Review underway
carbaryl	carbamate	
chlorpyrifos	organophosphate	
diazinon	organophosphate	Review underway
dichlorvos	organophosphate	Review underway
dimethoate	organophosphate	
endosulfan	cyclodiene	Approvals revoked
fenitrothion	organophosphate	
methamidaphos	organophosphate	Review underway
parathion-methyl	organophosphate	Approvals revoked
trichlorfon	organophosphate	Review underway

Reviews have already been completed for some, and the registration approvals revoked (endosulfan, parathion-methyl). Other reviews of insecticides are underway or shortly to be undertaken (dichlorvos, trichlorfon, azinphos-methyl, diazinon, methamidophos and acephate). Of those insecticides, dichlorvos trichlorfon, diazinon, and methamidaphos have current registrations for use on pastures or forage crops (Tables). ERMA has developed methods to take into account potential exposure and compares this to a more composite measure of hazard which, in turn, helps rank pesticides and the order in which reviews will be undertaken from 1 July 2010 (http://www.ermanz.govt.nz/resources/publications/pdfs/CEIR%20consultation%20document.pdf). The CEIR list is intended to be a 'living' list, subject to change as new substances or hazards are identified.

The outcomes from an ERMA review can be cancellation of a registration, the imposition of other controls, or no change to current status of a product. If the ERMA reviews ultimately revoked the registrations of all insecticides listed in Table 35 above, then the remaining available products for insect pest control on pastures and forage crops would be as shown in Table (assuming no new products enter the market in the short to medium term, refer to section 2.6 below).

Table 36: The availability of insecticides for control of key pasture and forage crop pests should all the active ingredients on the ERMA review list have their registration revoked (bolded registrations potentially revoked).

Active ingredient	ASW	CRW	GG	AW	POR	DBM	WB	APH	NWB	SPR	GCW	ERMA CEIRL[1]
alpha-cypermethrin				Y							Y	
carbaryl				**Y**								Listed
chlorpyrifos	**Y**	**Y**	**Y**	**Y**	**Y**			**Y**	**Y**	**Y**	**Y**	Listed
clothianidin	Y		Y							Y	Y	
deltamethrin						Y	Y	Y			Y	
diazinon			**Y**	**Y**	**Y**	**Y**		**Y**		**Y**		Listed
dichlorvos								Y				Listed
diflubenzuron					Y					Y		
dimethoate								**Y**		**Y**		Listed
es-fenvalerate				Y		Y	Y					
fenamiphos[3]												
fenitrothion				**Y**	**Y**			**Y**	**Y**	**Y**		Listed
furathiocarb	Y									Y		
imidacloprid	Y		Y					Y	Y	Y		
lambda-cyhalothrin						Y	Y	Y			Y	
lambda-cyhalothrin/primicarb						Y	Y	Y				
maldison						Y	Y	Y				
methamidaphos				**Y**				**Y**				Listed
methomyl				Y							Y	
oxamyl	Y											
permethin/primiphos-methyl						Y	Y		Y			
phorate	Y		Y					Y	Y	Y		
pirimicarb								Y				
Serratia			Y									
tau-fluvalinate								Y				
terbufos	Y		Y					Y	Y	Y		
thiamethoxam	Y							Y		Y		
trichlorfon				**Y**	**Y**	**Y**	**Y**				**Y**	Listed

[1] ERMA Chief Executive Initiated Reassessment List (CEIRL)

Of the 28 insecticides registered for use against pasture and forage crop pests, only eight active ingredients are currently or will shortly be under review by ERMA. Greatest impact arising from any future revoking of registrations would come from the removal of chlorpyrifos, diazinon and fenitrothion because those active ingredients occur in products with label claims for five or more key pests. Of the key pasture and forage pests, revoking insecticide registrations would have the greatest impact on porina with four of the five registered products potentially being removed. Approximately half the registered insecticides for armyworms and springtails could be removed, and although six active ingredients for aphid control could potentially be removed there are at least another 10 active ingredients that could be used to control these pests. It should be recognized that any insecticide product is at risk from being removed from a market due to the decisions made by the regulatory authorities in other countries and/or the manufacturers and distributors of insecticides.

2.5 Review of insecticides in other countries

In accordance with Directive 91/414/EEC, the European Commission in 1993 launched a programme on the Community-wide review for all active substances used in plant protection products within the European Union. In this review process, each substance had to be evaluated as to whether it could be used safely with respect to human health (consumers, farmers, local residents and passers-by) and the environment, in particular groundwater and non-target organisms, such as birds, mammals, earthworms, bees. A major 16 year review of over 1000 pesticide active ingredients was completed in 2008 and 250 active ingredients were passed the EU assessment and placed on a database (http://ec.europa.eu/sanco_pesticides/public/index.cfm, accessed 10-02-10).

Active ingredients that met these safety criteria have been placed in the 'positive' list or Annex 1. In the European Community, plant protection products should not be used by member states unless they fulfill the conditions laid down in Annex 1. There is a complex set of continuously evolving regulations surrounding pesticide legislation in Europe, but it is suffice for this project to identify which pesticides currently registered in New Zealand are included (or not) in Annex 1. The implication is that if an active ingredient is not permitted by European trading partners, then any agricultural product produced in New Zealand with those active ingredients may not be acceptable to those trading partners. Insecticides registered for use on pastures or forage crops in New Zealand and their status with regards to Annex 1 is shown in Table 37.

In the United States, the Environmental Protection Agency (EPA) initiated a new program in 2006 called the 'Registration Review of Registered Pesticides' to reevaluate all pesticides on a regular cycle. The programme's goal is to review each pesticide active ingredient every 15 years to make sure that as the ability to assess risks to human health and the environment evolves and as policies and practices change, all pesticide products in the marketplace can still be used safely. The EPA may also initiate a 'Pesticide Special Review' process when it discovers that the use of a registered pesticide may result in unreasonable adverse effects on people or the environment. Unlike the re-registration and registration review processes, the special review process usually involves intensive review of only a few or just one potential risk concern. The review involves evaluating existing data, acquiring new information and/or studies, assessing the identified risk, and determining appropriate risk reduction measures (http://www.epa.gov/oppsrrd1/reevaluation/, accessed 10-02-10).

The American Bird Conservancy (ABC) requested that the Environmental Protection Agency (EPA) revoke the import tolerances for the following pesticides (underlined ones are those registered for use on pastures or forage crops in New Zealand): cadusafos, cyproconazole, <u>diazinon</u>, dithianon, diquat, <u>dimethoate</u>, <u>fenamiphos</u>, mevinphos, <u>methomyl</u>, naled, <u>phorate</u>, <u>terbufos</u>, and <u>dichlorvo</u>s. These pesticides are highly toxic to birds, and are used in crops that many species of U.S. migratory birds use as habitat (http://www.abcbirds.org/newsandreports/releases/090730_petition.html, accessed 10-02-10).

Those insecticides registered for use on pastures and forage crops that are currently under review by the EPA are shown in Table 37.

Table 37: Status of assessments carried out by the European Community and the US Environmental Protection Agency for insecticides registered for use on New Zealand pasture and forage crops.

Active ingredient	EC Annex 1	US EPA Review
alpha-cypermethrin	yes	Not currently under review
carbaryl	no	Not currently under review
chlorpyrifos	yes	Not currently under review
clothianidin	yes	Not currently under review
deltamethrin	yes	Not currently under review
diazinon	no	Under review, final decision 2014, petition to revoke tolerances
dichlorvos	no	Final decision pending, petition to revoke tolerances
diflubenzuron	yes	Not currently under review
dimethoate	yes	Under review, final decision 2015, petition to revoke tolerances
es-fenvalerate	yes	Review planning underway
fenamiphos	yes	Petition to revoke tolerances
fenitrothion	no	Under review, final decision 2012
furathiocarb	no	Not currently under review
imidacloprid	yes	Under review, final decision 2016
lambda-cyhalothrin	yes	Not currently under review
lambda-cyhalothrin/primicarb	yes/yes	
maldison	no	Under review, final decision 2015
methamidaphos	no	Voluntary registration cancellation 2009
methomyl	yes	Not currently under review, petition to revoke tolerances
oxamyl	yes	Not currently under review
permethin/primiphos-methyl	no/yes	
phorate	no	Under review, final decision 2014, petition to revoke tolerances
pirimicarb	yes	Not currently under review
Serratia		
tau-fluvalinate	no	Not currently under review
terbufos	no	Under review, final decision 2014, petition to revoke tolerances
thiamethoxam	yes	Not currently under review
trichlorfon	no	Under review, final decision 2015

It is not possible to predict the outcome of US EPA reviews or whether insecticides will remain on the EC Annex 1 list, given that there are ongoing reviews in both legislative jurisdictions. However, there is general consistency between the ERMA reviews, EC Annex 1 and the US EPA reviews in the identification of certain organophosphate and carbamate insecticides that may not be available to pastoral farmers in the short to medium term. Further, it is interesting to note that imidacloprid is under review by the EPA in the US, and there have been calls for it to be reviewed elsewhere, e.g., EU. This possibly foreshadows the risk of losing another insecticide that has fulfilled a very useful niche in control of pasture and forage seedling crop pests.

2.6 New Zealand commercial perspectives on insecticides for pastures and forage crops

The registration of pesticide products in the New Zealand market presents a range of challenges for agrichemical companies. These can be briefly summarized as follows.

- By world standards, the agrichemical market in New Zealand is very small. This is particularly true for insecticides that comprise around 10% of total pesticide sales in New Zealand averaging around

300 tonnes of active ingredient per annum. Small markets mean reduced opportunities for establishing new products because the cost of development and registration relative to sales may not be favourable.

- If new insecticide products are introduced to the market in New Zealand, then their use in a number of production sectors would desirable. It is quite unlikely an insecticide would be developed and registered solely for use on pasture and forage crops, and possible uses in intensive horticulture would likely be considered before uses in pasture and forage crops.
- For existing products, there is an issue relating to data protection which currently does not afford sufficient confidentiality of data submitted for registration especially with active ingredients outside the patent protection period. Therefore, there is little or no incentive for agrichemical companies to extend registrations of existing products that would be accessible to third parties to utilize the same data to gain a registration and, therefore, complete in the market with a product similar to that developed by the original registrant of a product. One active ingredient (confidentiality requested by company) which could have had applications for grass grub control in pastures will not now be pursued because of sufficient lack of data protection. The data protection issue is discussed more fully on the AGCARM website (http://agcarm.co.nz/wp-content/uploads/final-submission-data-protection-discussion-paper-agcarm-sept-2009-3.pdf, accessed 12-02-10).

Commercial considerations can also affect the availability of existing insecticide products in the New Zealand market. These could include:

- Sales of a product may not be commercially sustainable and, therefore, a company may decide to withdraw a product.
- For older product chemistry, there may be little or no remaining technical support or supply of an active ingredient, and therefore maintenance of a product in a market becomes unviable.
- For some products, e.g., granular systemic insecticides that are drilled with seed at crop or pasture establishment, these may become commercially marginal as a consequence of greater use of systemic seed treatment active ingredients.
- The removal of an insecticide product in New Zealand may be dictated by the withdrawal of that product by the company in other countries.

From contact with commercial companies in New Zealand, a general consensus about the prospects for insecticide registrations for pasture and forage crops is as follows:

- Companies generally will consider all options for new products in all sectors of New Zealand agriculture and horticulture, however, the decision to commercialize a product is complex.
- Most companies are coy about revealing too much about prospects for new insecticidal products, but it would seem the timeline for introduction of new products is more likely in the range of 5-10 years rather than 2-3 years.
- It is likely that pasture and forage crop pests are ‘well down the list’ for consideration with new products, unless they are pests in common with some horticultural crops, e.g., brassica pests.
- Older insecticidal products will inevitably be removed from the market through either regulatory or commercial pressures. The removal of products could be quite rapid, or phased out over a number of years.
- The pasture and forage crop market for insecticides is generally not as favourable as it has been in the past given the more recent development of non-chemical controls for common, the fluctuating

economic fortunes of pastoral production (dairying excepted), and awareness of market requirements for agricultural products largely free of pesticide residues.

If product registrations are an index of commercial viability of insecticide products for use on pasture and forage crops, then Tables 3 and 4 illustrates:

- A range of insecticides largely dominated by organophosphate active ingredients that have persisted in the market for decades (with a few being withdrawn at intervals).
- Virtually no new insecticide active ingredients being registered during the past decade.
- Newer insecticide products are largely neonicotinoid active ingredients with registrations for use as seed treatments.

At present there appears to be a sufficient range of insecticides registered for control of key pests of pasture and forage crops in New Zealand. Product withdrawals in time (sections 2.4 and 2.5 above) could seriously limit options for insecticidal control of some pests, e.g., porina.

2.7 Summary for section two

- The intensification of New Zealand agriculture has, in part, relied on pesticides to combat pest orgamisms. In the modern chemical era of synthetic insecticides (1960s onwards) insecticides from a range of chemical classes (organochlorine, organophosphate, carbamate, pyrethroid, benzoyl phenyl urea, neonicotinoid) and microbial insecticides (*Serratia* sp., *Bacillus* sp.) have been used against pasture and forage crop pests.
- In 2010, there were 28 insecticidal active ingredients in over 60 commercial products registered for insect (and nematode) control on pastures and forage crops. The active ingredients are dominated by organophosphates (11), pyrethroids (6), carbamates (5), neonicotinoids (3),benzoyl phenyl urea (1), microbial (1) insecticides.
- Twenty six pest species (or related groups) have registered uses listed on insecticide product labels. The number of active ingredients for each pest species (or group) is: Argentine stem weevil (7), black beetle (3), clover root weevil (1), grass grub (7), Sitona weevil (3), Tasmanian grass grub (3), weevils (unspecified)(3), armyworm (6), clover casebearer (2), corn earworm (7), diamondback moth (8), greasy cutworm (7), porina (5), white butterfly (6), aphids (all species)(13), green vegetable bug (1), wheat bug (3), mirids (1), Australian soldier fly (1), brassica leaf miner (1 combination product), black field cricket (1), thrips (1), springtails (11), redlegged earth mite (1), plant parasitic nematodes (2).
- Reviews of 10 insecticide active ingredients used on pasture and forage crops are currently under way (or due to be reviewed soon). Many of these insecticides (mainly organophosphates) are not listed on Annex 1 of permitted pesticides for the European Community, and many of the same active ingredients are under review by the US EPA. The availability of these active ingredients in the short to medium term (up to 5-7 years) is uncertain.
- Removal of organophosphate and carbamate insecticides could increase the risk of resistance development by some pests to other classes of insecticides.
- The ongoing commercial availability of some older insecticides in New Zealand is in doubt because of low sales volumes, lack of technical support and supply, or regulatory review of registrations. Prospects for the introduction of new insecticide active ingredients appear to be quite limited given the small market size for most products on pasture and forage crops, lack of sufficient data protection for agrichemical companies and other commercial considerations.

3.0 References

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4.0 Appendix

Appendix 1: Molluscicides registered for use on pastoral land in New Zealand, 2010 (Source: New Zealand Novachem Agrichemical Manual, 2010, web version).

Active ingredient	Trade products[1]	Comments
iron EDTA	Mulitguard Snail and Slug Killer	No recommended uses for pasture or forage crops.
metaldehyyde	Endure, Metarex, Slug Out, Donaghys Slugicide	Bait formulations with 18-50 g metaldehyde/kg applied either as broadcast or in furrow treatments. Some products have no recommended use for pasture or forage crops.
methiocarb	Mesurol Snail and Slug Bait, Mesurol Pro Snail and Slug Bait	No recommended uses for pasture or forage crops.
thiodicarb	Larbate	No recommended uses for pasture or forage crops.

[1] When multiple products containing the same active ingredient are available, examples only of those products are listed in this column. There may be slight variations from one product to the next with the formulation and amounts of active ingredient, and therefore application rates may vary slightly. The onus is on all users of pesticides to follow label instructions. For further information on molluscicide products refer to the New Zealand Novachem Agrichemical Manual.