Know-how for Horticulture™

Development of an integrated pest management program in celery

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IPM Technologies Pty Ltd

Project Number: VG99070

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This report is published by Horticulture Australia Ltd to pass on information concerning horticultural research and development undertaken for the vegetable industry.

The research contained in this report was funded by Horticulture Australia Ltd with the financial support of the Vegetable Industry.

ISBN 0 7341 0898 2

Published and distributed by:
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Final Report

DEVELOPMENT OF AN INTEGRATED PEST MANAGEMENT PROGRAMME IN CELERY

Project Number: VG99070

Prepared by: Dr Paul A. Horne
IPM TECHNOLOGIES PTY LTD

Executive Summary

Starting point

Prior to the commencement of this project, there was very little grower awareness of the many different species of pests that could cause damage, and practically no awareness that beneficial insects (predators and parasites of pests) existed within celery crops.

The approach to dealing with pests was regular and often frequent applications of broad-spectrum insecticides. This approach meant that aphid-borne diseases such as celery mosaic virus had became worse over time, as natural enemies of aphids were systematically prevented from living in celery crops but aphids were not all killed. Resistance to insecticides by some pests meant that the standard reliance on insecticides meant that a new approach was required.

Development

This project allowed identification of both major and minor pests of celery. These are listed in this report. Following the identification of these pests, specific control measures were developed. These control measures include identification of biological control agents, cultural (management) techniques, and selective or strategic use of chemicals.

Efficacy trials were suggested for registration of products, and this was carried out in a separate project by Crop Protection Approvals. As a result, celery growers have access to insecticides that are compatible with an IPM approach.

Demonstration

The regular and frequent, direct contact between researchers in this project and growers has allowed a unique development to take place. Celery growers have learned the elements of integrated pest management (IPM) and implemented it immediately. They have been prepared to apply the recommendations of researchers because they were deeply involved in the assessment and decision-making process.

This regular contact between researchers and growers has instilled confidence in applying new processes. From a growers point of view, if the advisor does not believe in their advice, why should the grower? Therefore, in this project, the researcher stood in the farmers paddock each week and gave advice, and then assessed the outcome of that advice the next week.

Field Days were run but the growers using IPM were already aware of everything that the researchers had to say. Some growers did attend, but in the main, chemical resellers were the dominant attendees at these days.

Such a result was not unexpected or undesirable. The information on IPM in celery was extended to a wider audience.

Adoption

Major growers

IPM logo

Participating growers in this project were:

- J. & J.M. Schreurs and Sons (Tom, Theo and Adam Schreurs)
- Peter Schreurs and Sons (Darren Schreurs)
- L. & G. Gazzola and Sons (Paul and Andrew Gazzola)
- Corrigan's Farm (Geoff and Deborah Corrigan)
- Favero Farms (Glen and Silvio Favero)

This is a small number of growers, but these growers produce the vast majority of celery in Australia. Of this group of five farms, the first three are using, or plan to use, an IPM logo on their cartons. This proves the success of the implementation component of this project. Of the remaining two farms, one uses an IPM approach now to all crops they grow, not just celery. The fifth farm has heavily modified their insecticide use as a result of this project, but have not fully adopted IPM.

Guide to IPM in celery

This report contains a guide to the species of most interest in celery and methods to monitor the pests. Identification of these insects is possible using some of the currently available guides to insects in other horticultural and broad-acre crops. If required, this section of the report could be used as a stand-alone document.

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Summary of Activities and Achievements

General

This project aimed to develop an IPM strategy for celery and to demonstrate that IPM strategy to celery growers. Both activities occurred at the same time, as growers actively took part in the decision-making process.

The methodology consisted of staff from IPM Technologies P/L visiting participating grower's farms once per week, assessing the insect situation in terms of pests and beneficial species, and making a decision on any pest management actions required. At least two sites were monitored on each farm, to cover different aged plantings.

This methodology allowed several activities to be performed concurrently:

1. A list of pest species and the damage they caused was compiled
2. Species that were present but that did not cause damage to celery were identified
3. Seasonality of key pests was documented
4. Growers became able to recognise both pest and beneficial species
5. Growers were comfortable with decisions because they could see why they were made
6. Researchers from IPM Technologies were able to extend information and see it adopted during the life of the project, not after the completion of the project.
7. The regular direct contact with growers allowed confidence in IPM to be developed, and so control measures based upon biological agents and management techniques usually replaced reliance on insecticides

Participating growers in this project were:

- J. & J.M. Schreurs and Sons (Tom, Theo and Adam Schreurs)
- Peter Schreurs and Sons (Darren Schreurs)
- L. & G. Gazzola and Sons (Paul and Andrew Gazzola)
- Corrigan's Farm (Geoff and Deborah Corrigan)
- Favero Farms (Glen and Silvio Favero)

This is a small number of growers, but these growers produce the vast majority of celery in Australia.

Project Milestones:

Description and Achievement criteria:

- **IPM demonstrated on farm to participants**
- **Demonstrations as scheduled, and field trials commenced**
- **Initial field trials completed**

- **Field Day conducted**
- **Complete field days and demonstrations**
- **Final Report**

Research Provider: **IPM Technologies Pty Ltd**
Principal Investigator: **Dr Paul A. Horne**

Summary of Achievements and Outputs

Demonstration of integrated pest management (IPM) in celery

This project has been very successful in providing celery growers with a demonstration of how IPM can help to control pests. In addition to simply demonstrating what is **possible** using IPM, the project has convinced all the farmers involved in the trial to **implement** IPM in their celery crops, and on other crops that they grow. That is, the demonstration showed farmers how IPM was a better method than conventional spraying for whatever crop is considered.

In the early stages of this project, we identified the major pests of celery. Despite being an apparently simple task, growers could not say what insects were really a problem other than list "aphids and caterpillars" as pests they routinely encountered. This is because their previous management relied on a routine spray programme with broad-spectrum insecticides, and so growers did not need to be too accurate in pest identification.

Entomologists from IPM Technologies P/L visited participating grower farms each week since the commencement of the project. On each visit the degree of risk posed by each species of pest, and the level of control likely to be provided by beneficial species, was assessed and discussed with the grower. The result has been a significant reduction in insecticide use in the crops being monitored.

Monitoring for aphids in particular allowed immediate reductions in pesticide use. Timing of other insecticides for caterpillars allowed further reductions in pesticide applications and also better results with less harmful products. There were large differences in the timing of sprays between different regions where celery is grown.

Identification of the real pests in celery

The very first step in this project was to determine what insects were really of concern in celery in Australia. There were many misconceptions of pests, lack of knowledge that some pests were present, and almost total lack of understanding about the presence and potential of beneficial insects in celery. This project has changed that situation, and now growers and advisors are aware of the species that are of real concern and the role of beneficial insects and mites.

The initial discussions with celery growers at the beginning of this project could only identify "aphids and caterpillars" as major pests. The approach to dealing with these at that time was applying regular and frequent insecticides. The development of an IPM approach obviously depended on being much more specific in terms of what species were of concern.

Helicoverpa (Heliothis) armigera was clearly the most important caterpillar pest during this project. Pheromone trap captures indicated the seasonality and so major risk periods of damage from this pest (figure 1).

A summary of the key pests and beneficials, and how to monitor for them is provided in this report in the form of an IPM Guide.

Identification guides to both the pest and beneficial species occur for other industries, including several horticultural industries. Neither the pests nor the beneficials described here are restricted to celery crops.

The major pests identified in this study are:
Helicoverpa (Heliothis) armigera
Aphids, especially Green Peach Aphid, *Myzus persicae*
Cutworm caterpillars (*Agrotis* species)

Pests found regularly but of less importance include:
Helicoverpa (heliothis) punctigera
Thrips (onion thrips, *Thrips tabaci*)
Vegetable weevil (*Listroderes difficilis*)
Lightbrown apple moth (*Epiphyas postvittana*)
Looper caterpillars (*Chrysodeixis argentifera*)

Minor Pests include:
Slugs (*Deroceras reticulatum* and *Milax gagates)*
European Earwigs (*Forficula auricularia*)
Earthworms (contaminants in produce)

Adoption

There has been an extremely rapid adoption of IPM as a result of this project, and this is clearly due to the farmers being able to see the strategy demonstrated on their own crops, and real decisions being made each week. The success of this project is given by the fact that growers have used the celery model to begin IPM on other crops as well. The rapid adoption of IPM achieved through this project stands in contrast with most reported rates of adoption of IPM in crops throughout the world (Ref: Herbert, D.A. 1995, Integrated pest management systems: back to basics to overcome adoption obstacles. *Journal of Agricultural Entomology* ***12:*** *203-210*).

Regular (weekly) visits by entomologists from IPM Technologies P/L to participating growers' farms each week are the key to the rapid rate of adoption of IPM. On each weekly visit, management options have been discussed with the grower and recommendations regarding the selection and use of insecticides (if necessary), have also been made each week.

There is no doubt that the first-hand contact between IPM specialists and the growers, making site-specific decisions, is an important means of implementing change.

Pesticides within an IPM strategy

We have conducted field and laboratory trials to determine how effective and how selective certain new pesticides are, and how appropriate they are within an IPM programme. Trials with spinosad and GemStar have shown that these products would be far more suitable to control Heliothis (a key pest) than the currently available products. Trials were organised with Crop Protection Approvals to obtain registration of these products, as a result of this project.

Spinosad ("Success") and "GemStar" are far less disruptive to most beneficial organisms, and so to any IPM strategy. GemStar is a virus that is only effective on *Helicoverpa* spp. and so correct identification of other caterpillar pests (eg. cutworm, loopers, lightbrown apple moth) is more important than under a conventional broad-spectrum spray-based control programme.

Field Day

A field day to explain how IPM in celery can be carried out was conducted on the property of J. & J.M. Schreurs and Sons in September 2002. In addition to celery growers, staff from E.E. Muir & sons were present and were very interested in finding out about IPM and the details of how to monitor for beneficial insects.

This project, and IPM in celery in general, have been reported in the newsletter VegeLink, by Patrick Ulloa (Industry Development Oficer), and in the Southern Farmer newspaper (August issue) and Good Fruit and Vegetables magazine.

Change in pesticide use

Confidential grower surveys of previous use of insecticides were made during the project. At certain times of the year (summer) when pests were abundant and damage was occurring, some very heavy pesticide use had occurred. For example, one grower used 2 insecticides at a time over a 12 week period, plus one more when damage still occurred. That is, a total of 25 insecticides in 12 weeks.

The insecticides used prior to this project belonged to the organophosphate, organochlorine, carbamate and synthetic pyrethroid groups. That is, non-selective, broad-spectrum insecticides.

All growers involved in this project decreased insecticide use. The change was significant, not only in the volume of pesticide used but in the type used. Before the project, all growers routinely used insecticides for aphids, and subsequently have used selective aphicides just a few times in a year.

The outcome for the industry has been a significant reduction in reliance on insecticides and confidence in an IPM approach. This has resulted in decreased costs and a higher quality end product.

Several growers involved in this project are either using, or intending to use, a logo on their cartons stating that their produce was grown using IPM. These are:

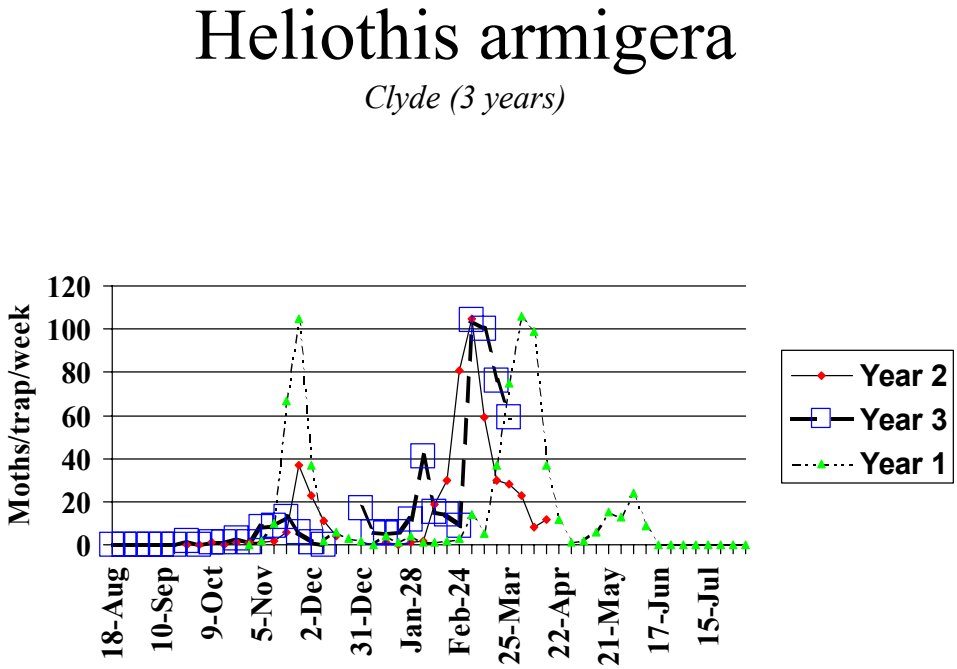
- J. & J.M. Schreurs and Sons
- Peter Schreurs and Sons
- L. Gazzola and Sons.

Other growers taking part in this project, who have modified either a little or a massive amount in their approach to pest management include:

- Corrigan Farm
- Favero Farms

In total, the growers listed above produce over 80% of the celery grown in Australia, and 3 of this group of 5 see IPM as integral to their businesses.

Figure 1: Pheromone trap captures over 3 years from celery crops in Clyde, Victoria, showing the seasonal occurrence of the major pest, *Helicoverpa (Heliothis) armigera*.



A Guide to IPM in Celery

Introduction

There are hundreds of different insect species that can be found in most vegetable crops. A few are pests, but most are either beneficial (helping to control pests) or benign (neither pest nor beneficial). Monitoring the insects regularly throughout the life of the crop, and even before planting in some cases, allows you to know exactly what types of insects are present and determine the risk of damage. Controlling the pests in a sustainable way is best achieved through an Integrated Pest Management (IPM) approach, which involves using cultural, biological and chemical measures in a compatible way.

The risk of damage will depend on many more factors than just the number of pest insects found during monitoring. Information on the numbers of pest and beneficials found is necessary to allow an accurate assessment of risk to be made. Other factors that influence the likelihood of damage are:

1. The type of beneficial insects present (do they feed on the pest concerned?)
2. The end-use of the crop (local, export)
3. Irrigation (type and timing)
4. Time of year
5. District in which the crop is grown
6. Time of planting (early or late crop)
7. Pesticide use
8. Soil management
9. Variety of celery

10. Harvest date

Integrated Pest Management

Cultural Controls and **Biological Controls** are the main elements of any IPM strategy. Important **cultural controls** that impact on pest management in celery are:

(i) weed management (avoid carryover of pests on alternative hosts)

(ii) variety (some varieties are more susceptible to diseases)

(iii) quality of seedling source

(iv) screening glasshouses to exclude disease vectors

(v) Planting and harvesting cycles (avoid planting next to areas being harvested)

(vi) Break crops

(vii) Awareness of adjacent crops and pests (eg. weevils, thrips, aphids)

Biological control agents may be predators, parasites or pathogens. Insect predators and parasites are extremely common and are largely responsible for "unseen" control. They reach where pesticides cannot, and can achieve high levels of control, but they are highly vulnerable to most insecticides. Additional control is often required and if compatible sprays are used that do not kill these beneficial agents then you will have both sprays and beneficial insects working for you. If pesticides are applied that kill beneficial insects then you only have pesticides on your side. Regular monitoring is the only way to know the current situation regarding numbers and control given by biological control agents.

In an IPM strategy, **chemical control** is used to back up cultural and biological controls and should not be seen as the primary control method. When necessary, chemicals that assist biological control should be used rather than those that destroy

biological control. For example, border sprays can be a useful support strategy in an IPM programme.

Protocol for sampling celery crops

The sampling should tell you what type of insects are present, and also what life-stage is common and how many there are. Several different methods can be used together to collect this information. For example, we usually use pheromone traps, sweep-net or suction samples and leaf-counting to sample a crop.

Who should sample?

Anyone that can follow the protocol outlined here can conduct the monitoring if they can accurately identify the insects collected and can interpret the results. They must also make the monitoring work part of a routine and so must have the time to do it without missing weeks. Independent help may be the best way to ensure accurate advice is available on time.

When to sample?

Sampling should be carried out at weekly intervals. Choose a day and make the sampling part of the routine for that day. Eg. First thing Thursday.

Where to sample?

It is impossible to look through the entire crop, so pick a place, or several places, in the crop that you think are typical of the crop or a particular planting. Traps can go on the edge of a paddock and leaf sampling can take place in the same area. What you need to do is select an area that will give you results that you can confidently expect to represent the crop.

Looking at 100 leaves is the basis for the main monitoring. We recommend looking at 2 leaves, one lower leaf one upper leaf, on each of 50 plants. In addition, inspect the inside bases of stalks for caterpillars and vegetable weevil.

Water pheromone traps should contain water plus detergent. Traps for heliothis and loopers can be on the ground or suspended from a stake above the crop. Delta traps with a sticky base for lightbrown apple moth should be suspended above the crop. Count the number of moths in each trap each week using a tea-strainer (water traps) or a scraper (sticky traps). Replace the water and detergent each week. Replace sticky bases when they are coated with dirt/ dust or insects.

What to look for:

1. Pests

Aphids

Green peach aphids (*Myzus persicae*), and many other aphids, are found on the underside of the lower leaves. Therefore, for green peach aphids, make sure you inspect lower leaves. Look on weeds such as nettles as well as crop plants. Record the numbers of wingless and winged aphids separately. Aphids are a problem because they vector disease, not because of direct feeding damage. If broad-spectrum insecticides are used on the crop, watch for aphid resurgence.

Yellow sticky traps and water traps can be used to monitor flights of winged adult aphids but will not monitor wingless populations resident in the crop. Traps alone are insufficient to provide information on aphids. Traps need to be placed/ suspended above the crop. (We attach them to a bamboo cane and tape them at the top and bottom). Place sufficient traps to provide information on population trends, and remember that each sticky trap needs to be inspected weekly and the results made available weekly to be of use in helping with control decisions.

Thrips may be mature (with wings) or immature (no wings). Plague thrips (*Thrips imaginis*) and onion thrips (*Thrips tabaci*) are common but are not usually serious pests. Onion thrips, tomato thrips (*Frankliniella schultzei*) and Western flower thrips (*Frankliniella occidentalis*) can vector tomato spotted wilt virus, and WFT is also of quarantine concern and monitoring can be undertaken with yellow or blue sticky

traps. Yellow traps will also catch aphids (see above). These traps will catch many insects in addition to thrips, and are good to see what is flying in the crop. However, if they are used to monitor Western flower thrips then each will have to be inspected under a microscope by someone who can identify different species of thrips.

Lightbrown apple moth (*Epiphyas postvittana*) is easily monitored using pheromone traps. Count the number in a trap each week. However, the number of caterpillars on leaves (rolling them) should also be counted. It is very possible that other related species are local problems on some farms and these will not be detected by pheromone trapping. Therefore, direct searching for caterpillars or eggs is necessary.

Heliothis (*Helicoverpa punctigera* and *Helicoverpa armigera*) can be monitored by pheromone traps, but a more accepted monitoring method is to also count eggs, small, medium and large caterpillars.

Cluster caterpillars (*Spodoptera* sp) are monitored as for heliothis, distinguishing between eggs, and the different larval stages.

Loopers (*Chrysodeixis argentifera* and *Chrysodeixis eriosoma*) are counted as for heliothis if in high numbers.

Other caterpillars such as **cutworms** (*Agrotis infusa* and *Agrotis munda*) may be of serious concern in some years. These are found near the bases of celery plants and cause damage very similar to that of Heliothis.

Moth eggs, belonging to loopers or heliothis, are often found, but they do not always result in damage. It is useful to know what caterpillars are going to develop from these eggs before predicting damage or spraying.

Vegetable weevil (*Listroderes difficilis*) can cause serious damage to celery. The adult beetle walks into crops from surrounding paddocks or field margins and lays eggs. It is the larval stages that do most damage, and these shelter in the heart of young plants. The first signs of damage are small holes on the outer leaves. The larvae are easily distinguished from caterpillars as they have no legs.

Other insects, including grasshoppers, green or brown leafhoppers, mirid bugs and Rutherglen bugs are often found. Watch for invasions from a particular edge, rather than a general increase throughout the paddock.

Worms may be a contaminant requiring control in the field or disinfestation after harvest. Heavy watering can cause earthworms to move up to the soil surface and onto plants as oxygen levels fall.

Slugs (*Deroceras reticulatum & Milax* gagates) and snails (*Helix aspersa*) may be problems near road edges, or near hedges or dams. Border applications of molluscicide baits may be required.

European Earwigs *(Forficula auricularia*) can invade from shelter belts (grassy or hedge areas). Border treatments may be required.

Leaf-miners have not been seen as a problem, but are known to infest celery overseas. Controlling thistles is likely to be a key cultural method for keeping this problem at a minimum.

2. Beneficial Insects

In addition to knowing what pests are present, it is important to know what beneficial species are in the crop. Some of the most active species will be found on yellow sticky traps more than in the leaf-count.

We try to record the number of each beneficial species in 50 plants, and also presence/absence on the sticky traps. It is important to count aphid mummies (parasitised aphids).

When you need to be sure that good numbers of certain beneficial insects are present, then supplement the leaf count with sweep net samples.

Beneficial insects can be predators (which kill the pests immediately) or parasites (which kill more slowly).

Key species are:

Parasitic wasps (several species)

Micro-Hymenoptera (including aphid parasites, *Aphidius* spp)

Damsel bugs, *Nabis kinsbergii*

Shield bugs, Pentatomidae, *Oechalia schellembergii*

Mirids, *Creontiades spp.*

Green lacewings (adults and larvae), *Mallada signatus*

Brown lacewings, (adults and larvae), *Micromus tasmaniae*

Ladybird beetles

Transverse ladybird, *Coccinella repanda*

Common spotted ladybird, *Harmonia conformis*

Two spotted ladybird, *Diomus nitescens*

Red and blue beetles, *Dicranolaius bellulus*

Hoverflies (Syrphidae)

Tachinid flies (eggs seen as black specks on caterpillars)

Spiders: Web formers, jumping spiders and wolf spiders

Carabid beetles (Ground beetles, Carabidae) are likely to increase in number and importance as insecticides are reduced.

Applying Pesticides

When to use pesticides

In an IPM strategy, pesticides are used to support biological and cultural controls, as outlined in the introduction. It is very important to use pesticides only when required, particularly in order to avoid (i) insecticide resistance and (ii) inducing a worse pest problem than otherwise would have existed. The impact of a pesticide on overall pest management for the life of the crop should be considered, not only the effect on the target pest at one time.

The use of pesticides may be considered when pest numbers are likely to cause economic damage. The number of pests that can be tolerated will depend on the age of the crop, the type of pest, the time of year, the date of harvest and the value of the crop. Obviously, the use of pesticides should not cost more money than they save. Factors to consider are :

- The cost of the pesticide
- Application costs
- Disruption to biological control inducing pest outbreaks requiring further applications of pesticide
- Residues in produce causing crop rejection

What pesticides to use

Sprayable pesticides may be synthetic chemicals or may be biological (bacterial, viral or fungal). Entomopathogenic nematodes may be used in some systems. Table 1 shows an IDEAL example of compatible methods that comprise an IPM strategy. At present, hardly any have registration for use specifically on celery in Victoria, and registration of chemicals is different in different States. All are registered for use on the same or similar pests on other crops. Other non-compatible insecticides, which are much more hazardous to workers, crops, beneficial species and the environment, are registered for use on celery in Victoria.

TABLE 1: Ideal control options. *Note that not all products are registered on celery in Australia at this stage.*

Pest	Control method	Active Ingredient	Comments
Helicoverpa armigera *Helicoverpa punctigera* Heliothis	Predatory and Parasitic insects "Gem-Star" "Dipel", "Delfin" :Success" "Avatar"	Virus Bacillus thuringiensis Spinosad Indoxacarb	Virus Bacteria Spinosyn Use only early in the crop
*Agrotis s*pecies Cutworm	Predatory and Parasitic insects "Dipel", "Delfin" "Success" "Avatar"	Bacillus thuringiensis Spinosad Indoxacarb	Bacteria Use only early in the crop
Chrysodeixis argentifera *Chrysodeixis eriosoma* Looper	Predatory and Parasitic insects "Dipel", "Delfin"	Bacillus thuringiensis	Bacteria
Listroderes difficilis Vegetable Weevil	Border sprays (Carbaryl) Weed Management	Carbaryl	Carbamate
Epiphyas postvittana Lightbrown apple moth	Predatory and Parasitic insects "Dipel", "Delfin" "Success" "Avatar"	Bacillus thuringiensis Spinosad Indoxacarb	Bacteria Use only early in the crop
Aphids *Myzus persicae* and other species	Predatory and, Parasitic insects "Pirimor"	Pirimicarb	Carbamate
Aphids (in glasshouses)	Complete Screening Pirimor Confidor	Pirimicarb Imidacloprid	Carbamate Nitroguanodine
Fungus gnats Sciaridae	Nematodes Predatory mites	*Heterorhabditis* *Hypoaspis*	Available commercially
Earwigs *Forficula auricularia*	Weed management Border sprays		
Slugs *Deroceras reticulatum* *Milax gagates*	Weed management Rotary hoeing Baits	Methiocarb, EDTA Metaldehyde	Carbamate Iron chelate

Recommendations

There are two pests of celery for which control could be significantly improved with some more research and development.

1. A pheromone lure for the species of cutworm (*Agrotis spp.*) would give early warning and information on flight of these moths. I recommend that research funds be directed to developing such lures.
2. It is likely that species of *Epiphyas* closely related to *E. postvittana* (lightbrown apple moth) are pests of celery. I recommend that a small project be funded to identify the species involved and potentially, a pheromone to monitor that species.

Acknowledgements

I would like to thank all of the celery farmers who took part in this project, but especially Mr Tom Schreurs who initiated the project and Mr Theo Schreurs who was the first to try many of the novel approaches to pest management that we suggested. I would also like to thank Mr Patrick Ulloa for his support for this project, and all members of IPM Technologies P/L who took part in different aspects of the project.