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Pest Management for Organic Agriculture

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by Paul A Horne

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Researcher Contact Details
Dr Paul A Horne
PO Box 560
Hurstbridge VIC 3099

Phone: 03 9710 1554
Fax: 03 9710 1354
Email: ipmtechnologies@bigpond.com

In submitting this report, the researcher has agreed to RIRDC publishing this material in its edited form.

RIRDC Contact Details
Rural Industries Research and Development Corporation
Level 2, 15 National Circuit
BARTON ACT 2600
PO Box 4776
KINGSTON ACT 2604

Phone: 02 6271 4100
Fax: 02 6271 4199
Email: rirdc@rirdc.gov.au.
Web: http://www.rirdc.gov.au

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Foreword

This project tested both existing and new products for their effects on beneficial insects (predators and parasites) as well as on pests. It aimed to provide organic producers with a suite of compatible control measures that will increase the level of pest control and the control options available. The project also aimed to provide information on how growers can achieve more effective and more sustainable control of major pests by maximising biological control agents and suitable insecticides.

This project aimed to provide specific pest management recommendations for key pests in organic production. It tested the efficacy of pesticides suitable for organic production (that is, of botanical, elemental, viral, bacterial and fungal origin). This provided data to support registration of suitable products as well as information on the effects of the pesticides tested on beneficial insects and mites. It provided the basic information required for development of Integrated Pest Management (IPM) strategies. The project also tested the effectiveness of augmentative releases of mass-reared beneficial insects.

This project was funded from RIRDC Core Funds which are provided by the Australian Government.

This report, an addition to RIRDC's diverse range of over 1700 research publications, forms part of our Organic Systems R&D program, which aims to deliver R&D to facilitate the organic industry's capacity to meet rapidly increasing demand, domestically and globally.

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Peter O'Brien
Managing Director
Rural Industries Research and Development Corporation

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Abbreviations

AZA	azadirachtin
BT	*Bacillus thuringiensis*
DAT	days after treatment
ha	hectare
IPM	Integrated Pest Management
OFA	Organic Farmers of Australia

Contents

Executive Summary

What the report is about
This project examined the comparative effectiveness of pesticides that are available for use by organic producers and their effects on beneficial species, and whether natural populations of beneficial species can be augmented with commercially produced beneficial species.

Who is the report targeted at?
This report is targeted at farmers who are growing crops organically and are deciding the best method for dealing with pest problems.

Background
The three main methods of dealing with pest problems in agriculture are the use of pesticides, biological control agents and cultural (management) techniques. Farmers growing crops organically can use these three methods, but have imposed their own restrictions on the type of pesticides that can be used. This means that many organic producers are willing to put more effort or reliance on biological and cultural control techniques than other producers. It is important for organic producers that the pesticides that they do use are effective against the pests and do not interfere with any biological control. Organic producers will benefit by having a greater selection of more appropriate control methods, and this will lead to higher quality produce and more sustainable production.

Aims/Objectives
The aim of the project was to improve ecological sustainability and to minimise the effects of pesticides on non-target organisms. The project provided data on the impact of pesticides both currently used and that may be available in the near future.

Methods used
Laboratory trials were conducted to evaluate specific products against different species of insects, and field trials looked at the effects of augmentative releases of insects and mites. Suitable pesticides were tested in the laboratory for lethal and sub-lethal effects on pest and beneficial insects. Field trials were conducted to measure the impact of augmentative releases of beneficial insects.

Results/Key findings
Some of the products tested were highly effective against certain pests and safe to most beneficials (*Bacillus thuringiensis* sprays and Spinosad). However, most products tested did not have both efficacy in killing pests and safety to beneficial species. Although such a result may have been hoped for or believed by growers, most products that killed pests also killed beneficial species. The difference between these sprays and most conventional pesticides was in the time that residues would kill beneficial species. Almost all insecticides available for organic use had very short residual action and relied on direct contact with insects or mites.

Augmentation with beneficial species showed that addition of certain predators could make a significant difference to pest numbers and pest damage. However, in all cases releases needed to be made early in the life of either the crop or the season to have an impact. When releases of beneficial insects were made instead of spraying insecticides, then of course there was a greater abundance of many beneficial species, not only those being released. For example, in table grape vineyards where we released the main predators of mealybugs (*Cryptolaemus* and green lacewings), the control achieved was due to the combined effects of these predators plus other naturally occurring predators and parasites. Numbers of green lacewings in particular decreased markedly when district wide use of broad-spectrum synthetic insecticides began in December. This in turn resulted in a flare of mealybugs as newly emerged mealybugs were no longer eaten. We predicted a further increase in the problems with two-spotted mites as another consequence of predators being eliminated from the ecosystem. Recent reports confirm that this has eventuated.

Implications for relevant stakeholders

The role of beneficial species on pests is of relatively greater importance in organic agriculture than in conventional agriculture, because organic growers do not have recourse to the highly potent insecticides (such as synthetic pyrethroids) with which to tackle major pest problems. However, even major (multi-national) producers of synthetic insecticides recognise the importance of bio-control agents and are now producing a range of products which offer selectivity of action.

Recommendations

It is recommended that:

1. Growers need to know the results of pesticide testing.
2. Growers need to understand that several different tests are used to assess effects of pesticides.
3. Growers need to be able to identify beneficial species as well as pests.

Introduction

Background

Organic farmers do not use synthetic chemical pesticides but many rely heavily on naturally occurring beneficial insects and mites and/or just a few pesticides such as pyrethrum and BT-based insecticides. The level of control achieved with background beneficial insects is often insufficient, and the reliance on pyrethrum and BT is not sustainable, is expensive, and certainly not desirable in terms of pest management. Although permitted by organic associations, broad-spectrum insecticides such as pyrethrum can disrupt the long-term control of many pests by killing resident predators and parasites. There is a perception amongst many in the community that either no pesticides are used by organic growers, or those that are used have no detrimental effects. We set out in this project to provide some relative measure of the effects of several of the pesticides likely to be used by organic farmers.

Pest management needs to be measured not solely by the effectiveness of a single component (eg. a pesticide) but how well a pest or pest complex is controlled by a set of control measures. That is, how well can pesticides be integrated with biological and cultural methods to improve pest management. For example, a pesticide may not be the most lethal available, but overall control can be far superior if that pesticide does not kill beneficial species. This project attempted to assess how well suitable organic pesticides can fit into an overall pest management approach.

There is much research around the world investigating control of specific pests with either pesticides or biological control agents. Within Australia there are projects investigating control of diamondback moth in brassicas, and heliothis in cotton and chemical companies are producing new products (eg. “Success®”, “Applaud®”, “Regent®” “Gemstar®” in recent years) for use in these markets. However, while some of the information will be useful to organic growers, there is no integrated research looking at control of all insect pests in brassicas or cotton, using biological, chemical and cultural controls on either conventional or organic farms. Farmers need to be able to control all pests and need to know how controlling one species with a pesticide will impact on control of other pests. Most pesticides are not suitable for organic use, but a few (eg. Gemstar® and Success®), could be highly appropriate.

Data are available on the effects of many pesticides on commercially reared species of beneficial insects overseas (Koppert Pty Ltd 1998) but in Australia we have incomplete information on the effects of pesticides on commercially reared species (Llewellyn 2002) and extremely little information concerning native beneficial species. It is the native species of beneficial insects that organic growers currently rely on to control most of their pest problems, and so it is essential that effects of pesticides (even those allowed for organic use) on these species is known.

The current certified organic industry is worth approximately $250 million per annum with about 1500 operators. Many are small but about 500 are commercial. There are 7 certification organisations and one further likely to be accredited in the near future. Most growth is from international sales, with strong demand from Japan for fruit and vegetables and demand from Europe and the USA for grain, oil-seed and pulse products.

The major limitation to the expansion of the organic industry is the relatively small production. A high priority has been set by the OFA to assist conversion of conventional farmers to organic. Improving the prospects of pest control would certainly assist with this process. The results of this project will demonstrate to conventional growers that sound practical organic methods exist to control pests. The aim of the project is to improve ecological sustainability and minimise the effects on non-target organisms. The project provided data on the impact of pesticides, both currently used and that may be available in the near future. Organic producers will benefit by having a greater selection of more appropriate control methods, and this will lead to higher quality produce and more sustainable production.

Objectives

The overall objective of this project was to provide organic producers with a suite of compatible control measures that will increase the level of pest control and increase the control options available. The project also aimed to provide information on how growers can achieve more effective and more sustainable control of major pests by maximising biological control agents and suitable insecticides. This project tested both existing and new products for effects on beneficial insects (predators and parasites) as well as on pests.

One important aim of the project was to help organic producers to improve ecological sustainability and minimise the effects on non-target organisms. This report provides data on the impact of pesticides that are currently used, and some that are only just available or are not yet registered as pesticides in Australia.

Methodology

General description

There were two distinct components to this project; (1) laboratory trials and (2) field trials. Laboratory trials were conducted to evaluate specific products against different species of insects, and field trials looked at the effects of augmentative releases of insects and mites.

Laboratory trials

Suitable pesticides were tested in the laboratory for lethal and sub-lethal effects on pest and beneficial insects. The aim was to identify which pesticides are best for Integrated Pest Management strategies, not simply how well they kill pests. Insecticides were bioassayed in the laboratory by exposing insects to treated surfaces and, where appropriate, to treated prey or hosts. Measurements taken included mortality and survival through larval instars. Bioassays usually involved 5 replicates (each with 10 individuals) for each dose of each product being assessed. Mortality was usually measured after 24 hours, and then, where appropriate, every 2 to 3 days for 10 days. A range of doses was used for many products tested. Statistical analysis was achieved using analysis of variance. Significance is indicated in the results where appropriate.

Species tested were maintained in culture by IPM Technologies Pty Ltd for this work. They were reared and tested at 25°C.

Field trials

Field trials were conducted to measure the impact of augmentative releases of beneficial insects. These trials involved monitoring populations of pest and beneficial insects in commercial crops before and after augmentative releases took place. Replication was achieved by using a number of paddocks in a district, rather than plot trials within a paddock. Assessment in some cases was establishment, not the level of control achieved. Species used were parasitic wasps and predatory lacewings, ladybirds and mites.

Laboratory Bioassays

Species tested

A range of native species and some introduced pest and beneficial species were tested in the course of this project. Colonies of several insect species were either maintained by us, or commercial producers and included pest species such as Heliothis (*Helicoverpa armigera*), tomato leafminer/potato moth (*Phthorimaea operculella*), field crickets (*Teleogryllus commodus*), diamondback moth (*Plutella xylostella*), cutworm caterpillars (*Agrotis infusa*), two-spotted mite (*Tetranychus urticae*), greenhouse whitefly (*Trialeurodes vaporariorum*); and beneficial species such as common spotted ladybird (*Harmonia conformis*), Cryptolaemus ladybirds (*Cryptolaemus montrouzieri*), damsel bugs (*Nabis kinsbergii)*, red and blue beetles (*Dicranolaeus bellulus*), green lacewings (*Mallada signatus*), brown lacewings (*Micromus tasmaniae*) and the parasitic wasps (*Orgilus lepidus* and *Encarsia formosa*).

We used a standard protocol that allows us to compare the effectiveness of the products at different dose rates against pests, and also to compare what effects, if any, the products have on beneficial species. The bioassay involved treating plants by spraying with the candidate solution and, after drying, cutting leaflets which are kept alive in insect-proof containers. Insects were placed onto the leaflets and the mortality, or other measure such as egg count, was recorded at 2-7 day intervals. These results were compared to those obtained using the same insect species and life-stage on identical but untreated control leaflets. Another test involved spraying the product directly onto the test insect, not just treating the surface that the insect walked over.

Products/actives tested

A range of products that may potentially be used by organic producers was tested against both beneficial and pest species. The products included:

- garlic, chilli + pyrethrum, neem oil
- petroleum oil, vegetable-oils
- spinosad
- soap sprays
- citrus extracts
- diatomaceous earth
- silicates
- *Bacillus thuringiensis* (BT).

Field trials

Several field trials were conducted to assess the effectiveness of some insecticides or releases of beneficial insects.

One field trial was to test the effectiveness of neem (azadirachtin) on two-spotted mite in strawberries. This was a replicated trial, comparing the numbers of two-spotted mites on plants sprayed with the proposed label rate of “Neemazal” (active ingredient: 1% azadirachtin) versus unsprayed controls.

Releases of the predatory mite *Hypoaspis* were made in two commercial crops of baby spinach to see if there was a reduction in damage by crown gall mite.

Releases of the predatory mite *Hypoaspis* were also made in two commercial asparagus crops where symphylans (unknown species) were causing damage. These were inoculative releases to try and establish predators in the crops. 15,000 mites were released around the perimeter of paddocks affected. Releases were made in the worst affected areas at the rate of approximately 15,000 per 50 m^2.

Releases of green lacewings and Cryptolaemus ladybirds were made in indoor crops (roses) and in vineyards. Lacewings were released at rates of 1,000 per ha. With Cryptolaemus, the release rate of 1,000 Cryptolaemus (the main predator of mealybugs) per ha was the standard, but released either in one go (mass-release) or the total over several weeks (trickle release).

Detailed results

Effects of pesticides on pest and beneficial species

Trials with azadirachtin

The following tables indicate the mortality of beneficial species of insects when exposed to either direct contact with azadirachtin (AZA) or when given treated prey. Unless otherwise indicated, the rate of product used was 4ml/litre (highest label rate of product). Mortality was measured at the stated days after treatment (DAT) in each trial.

Table 1: Mortality of red and blue beetles, *Dicranolaius bellulus*, (adult beetles) when exposed to a surface treated with AZA., 3 DAT. Each replicate with 5 individuals.

Treatment	% Mortality
AZA 1	0
AZA 2	0
AZA 3	0
Control	0
Control	0
Control	0

Table 2: Mortality of red and blue beetles, *Dicranolaius bellulus*, (adult beetles) after being exposed to a direct spray of AZA, 3 DAT. Each replicate with 5 individuals.

Treatment	% Mortality
AZA 1	0
AZA 2	0
AZA 3	0
Control	0
Control	0
Control	0

Table 3: Mortality of red and blue beetles, *Dicranolaius bellulus*, (adult beetles) fed with AZA-treated prey (*Teleogryllus*), 7 DAT. Each replicate with 5 individuals.

Treatment	% Mortality
AZA 1	0
AZA 2	0
AZA 3	0
AZA 4	0
Control	0
Control	0
Control	0

Table 4: Mortality of the common spotted ladybird, *Harmonia conformis*, (final instar larvae) after being exposed to a direct spray of AZA, 4 DAT. There were 10 replicates each with one individual.

Treatment	Mortality
AZA 1	0
Control	0

Table 5: Mortality of common spotted ladybird, *Harmonia conformis*, (adult beetles) when exposed to a surface treated with AZA, 3 DAT. Each replicate with 5 individuals.

Treatment	% Mortality
AZA 1	0
AZA 2	0
AZA 3	0
Control	0
Control	0
Control	20

Table 6: Mortality of the common spotted ladybird, *Harmonia conformis*, (adult beetles) after being exposed to a direct spray of AZA, 3 DAT. Each replicate with 5 individuals.

Treatment	% Mortality
AZA 1	0
AZA 2	0
AZA 3	0
Control	0
Control	0
Control	0

Table 7: Mortality of damsel bugs, *Nabis kinsbergii*, (second instar nymphs) fed with AZA-treated prey (*Plutella*), 7 DAT. Each replicate with 5 individuals.

Treatment	% Mortality
AZA 1	20
AZA 2	20
AZA 3	0
AZA 4	0
AZA 5	0
Control	20
Control	20
Control	0

Table 8: Mortality of *Orgilus lepidus* (adult wasps) when exposed to a surface treated with AZA, 2 DAT. Each replicate with 10 individuals.

Treatment	% Mortality
AZA 1	0
AZA 2	0
AZA 3	0
AZA 4	0
Control	0
Control	0
Control	0
Control	0

Table 9: Mortality of green lacewings, *Mallada signatus*, (larvae) after being exposed to a direct spray of AZA at varying concentration, 4 DAT. There were 4 replicates each with 5 individuals.

Treatment	% Mortality
AZA (4 ml/ litre)	100
AZA (2 ml/litre)	95
AZA (0.4 ml/litre)	90
AZA (0.04 ml/ litre)	100
Control	10

All treatments significantly different to untreated control.

Table 10: Oviposition by *Plutella xylostella* on brassica leaves treated with azadirachtin spray, 4 DAT. There were 4 replicates each with 5 individuals.

Treatment	Number of eggs
AZA 1	148
AZA 2	52
AZA 3	48
AZA 4	60
Control 1	88
Control 2	57
Control 3	55
Control 4	83

Table 11: Mortality of *Plutella xylostella* (caterpillars) exposed to cabbage leaf leaves treated with AZA spray, 4 DAT and 7 DAT. There were 4 replicates each with 5 individuals.

Treatment	% Mortality 4DAT	% Mortality 7 DAT
AZA 1	70	100
AZA 2	50	100
AZA 3	60	100
AZA 4	50	100
AZA 5	60	100
Control	10	40
Control	20	20
Control	10	20

Significantly different to untreated controls.

Table 12: Mortality of black field crickets, *Teleogryllus commodus*, (first instar) placed on broccoli leaves treated with AZA at varying concentration, 7 DAT. There were 5 replicates per treatment, each with 5 individuals.

Treatment	Mean % mortality
AZA (4 ml/litre)	8
AZA (2 ml/litre)	8
AZA (0.4 ml/litre)	4
AZA (0.04 ml/litre)	12
Control	16

Chilli, garlic and pyrethrum

Table 13: Mortality of black field crickets, *Teleogryllus commodus*, when sprayed directly with chilli, garlic and pyrethrum, 4 DAT.

Treatment	Mean % mortality
Field rate	88
0.1 field rate	72
Control	12

Significantly different to untreated control.

Table 14: Mortality of black field crickets, *Teleogryllus commodus*, when placed on leaves treated with chilli, garlic and pyrethrum. There were 5 replicates of each treatment, each with 5 individuals.

Treatment	Mean % mortality
Field rate	28
Control	8

Soap sprays (NatraSoap®)

Table 15: Mortality of black field crickets, *Teleogryllus commodus*, (first instar) after treatment with soap spray, 7DAT. Both leaf and crickets were exposed to the spray. There were 5 replicates of each treatment, each with 5 individuals.

Treatment	Mean % mortality
Soap (20 ml/litre)	20
Soap (10 ml/litre)	12
Soap (2 ml/litre)	20
Soap (0.2 ml/litre)	12
Control	24

Table 16: Mortality of black field crickets, *Teleogryllus commodus*, (first instar) after treatment with soap (potassium oleate) plus citronella spray, 1 DAT. Both leaf and crickets were exposed to the spray. There were 5 replicates of each treatment, each with 5 individuals.

Treatment	Mean % mortality
Soap + citronella (40 ml/litre)	96
Control	0

Table 17: Mortality of cabbage moth, *Plutella xylostella*, after treatment with soap (potassium oleate) plus citronella spray, 1 DAT. Both leaf and crickets were exposed to the spray. There were 10 replicates of the sprayed treatment and 5 controls, each with 5 individuals

Treatment	Mean % mortality
Soap + citronella (40 ml/litre)	96
Control	0

Significantly different to untreated control.

Oil sprays

Table 18: Mortality of green lacewing, *Mallada signatus*, (larvae) sprayed directly with oil, 4 DAT. There were 4 replicates per treatment, each with 5 individuals.

Treatment	Mean % mortality
Oil (20 g/litre)	30
Control	0

Significantly different to untreated control.

Table 19: Mortality of Encarsia wasps, *Encarsia Formosa*, sprayed directly with oil, 3 DAT. There were 4 replicates per treatment, each with 5 individuals.

Treatment	Mean % mortality
Oil (20 g/litre)	87
Control	5

Significantly different to untreated control.

Spinosad

Table 20: Mortality of cutworm caterpillars, *Agrotis infusa*, following (a) direct exposure to a spray of spinosad (200ml/100L), or (b) exposure to a treated surface with the same rate of spinosad, 4 DAT. There were 7 replicates per treatment, each with 5 individuals.

Treatment	% Mortality
Direct exposure (a)	65
Untreated control (a)	9
Exposed to treated surface (b)	100
Untreated control (b)	9

Significant difference between treatments (P< 0.05).

Table 21: Mortality of common spotted ladybird, *Harmonia conformis*, (larvae) following (a) direct exposure to a spray of spinosad (200ml/100L) or (b) fed treated prey (aphids) exposed to the same rate of spinosad, 3DAT. There were 3 replicates per treatment each with 5 individuals.

Treatment	% Mortality
Direct contact	20
Fed treated prey	20
Untreated control	20

No significant difference between treatments.

Field Trials

Azadirachtin on two-spotted mite

This trial was carried out on a commercial strawberry farm on the Mornington Peninsula in Victoria to see the effect of Neemazal (active ingedient: 1% azadirachtin) on *Tetranychus urticae* (two-spotted mites) and on *Phytoseiulus persimilis* (predatory mite for two-spotted mites).

The strawberries (Selva variety) were grown outdoors, on ground covered by black plastic. There were two rows of strawberries in each row covered by the plastic and the plants were planted in a zig-zag pattern.

The trial site was chosen where the twospotted mite damage was most severe. Altogether 50 plants were used, so that there were 5 replicates, each with 10 plants. Plants were sprayed twice at 7 day intervals, using Neemazal at 4ml/litre (the highest label rate).

Table 22: Changes in numbers of two-spotted mite and predatory mites, 7DAT.

		Number of two-spotted mites		**Number of predatory mites**	
		Adults/nymphs	**Eggs**	**Adults/nymphs**	**Eggs**
1st replicate	treated	-18	-7	1	2
	Control	-8	0	3	5
2nd replicate	Treated	-4	0	8	5
	Control	-9	-5	12	9
3rd replicate	Treated	-9	0	12	10
	Control	-28	-15	10	20
4th replicate	Treated	-28	-15	19	20
	Control	-4	0	2	5
5th replicate	Treated	-7	-5	4	5
	Control	-20	-15	28	20

Augmentative releases of lacewings

Green lacewings (*Mallada signatus*) were released into commercial table grape crops in Robinvale (Victoria). They were released as first instar larvae at a rate of 1,000 per ha. When released into sites with mealybug problems early in the season then there was a much slower build-up of mealybugs. However, large releases of lacewings late in the season when mealybug numbers were high were not effective. Growers releasing lacewings early in areas without nearby use of broad-spectrum organophosphate insecticides gained good control of mealybugs. However, the results were achieved by a combination of what was released, and the higher level of naturally occurring predators and parasites in these sites.

“Trickle” releases over several weeks rather than the total released at one time was found to give better results.

Augmentative releases of predatory mites

Releases of the predatory mite *Hypoaspsis miles* were made in two different crops. These were commercial crops of spinach where crown gall mite caused damage, and in asparagus where a new pest (symphylids) were found. In both cases the predatory mites established in the crop but direct control of pests was not quantified. However, it was found that where these predatory mites were easily found then the incidence of damage was decreased. Cultural controls and past history of pesticide use are complicating factors in these field trials, and both are likely to influence the levels of damage and the numbers of beneficial species in any given area.

Effectiveness and hazard ratings for some pest control treatments

Treatment	Effectiveness	Hazard rating
Azadirachtin (neem)	Caterpillar control good Poor results on mites	Kills some predators
Spinosad	Caterpillar control good	Safe to most predators
Bacillus thuringiensis	Caterpillar control good	Safe to predators and parasites
Pyrethrum	Broad-spectrum	Kills predators and parasites
Oils	Broad-spectrum	Kills predators and parasites
Soap	Broad-spectrum	Kills predators and parasites
Citrus extracts	Low toxicity to pests	Safe to predators tested
Silicates	Broad-spectrum	Kills predators and parasites

Discussion of results

The results of laboratory testing indicate that, if used selectively, most products can have a place in an overall pest management programme, depending on the type of pest and the product. However, there were no outstanding products that killed a wide range of pests with no effects on beneficial species. In fact, the wider the range of pests killed, the more detrimental the effects on beneficial species. The results obtained in our trials show that simply being available for organic status does not make products immediately suitable for use in conjunction with beneficial species.

We tested neem products (azadirachtin) on many species of pest and beneficials and found that it was safe on most (but not all) predatory and parasitic species but was effective against only a few pests. It was highly effective against caterpillars in our testing. Spinosad was highly effective against caterpillars but was safe to the predators used in our tests. *We emphasise that we cannot extrapolate this to say it is safe for all predatory species*. Results can differ greatly between species and so we cannot conclude that spinosad is safe to all predators, but it is certainly not a broad-spectrum insecticide.

The type of testing undertaken is extremely important. In a recent review, it was stated that several pesticides were shown to be safe, as determined by laboratory screening (Hassan 1998), but it is known by workers in the field that this is simply not so (e.g. Nimrod® (bupirimate) and Applaud® (buprofezin) which are not organic products but for which the same principle applies). It is not just the product but the rate and frequency of use that will influence any toxic effects. I am also aware of very recent work that has pronounced several pesticides safe to beneficial species because the work has only tested dried deposits. If these pesticides can cause almost total mortality of beneficial populations through direct contact of spray droplets, then the results presented are totally misleading. The effects of oils available to organic growers fall into this category.

There is a ranking of harmful effects due to pesticides, from causing acute toxicity and having massive residual effects, to only having short-term acute effects or no effect at all. In between these two extremes are a range of sub-lethal effects that may have massive effects on populations of beneficial species (Hattingh 1996, Stark, Banken and Walthall 1998). It is true that even overhead irrigation can kill beneficial species such as *Trichogramma* wasp adults, so there are very few actions that are totally safe to beneficials.

The results presented here demonstrate that careful selection and timing of pesticide-use is required by organic growers or they could make pest problems worse. This would occur if pests are not totally controlled by the pesticide and in addition beneficial species are killed. The surviving pests would then have fewer natural enemies and would increase in number more quickly than if such beneficial species were present. We have seen exactly this situation occur in several organic and conventional crops (data not presented here), and the problem is well known and recorded in the scientific literature (New 2002, Haskell 1998).

Using beneficial species and cultural methods must be the two primary control methods for organic producers. If this is accepted, then it follows that pesticides must be used only to support these two measures, and should have minimal impact on beneficial species. Therefore, growers should consider carefully both the impact on target pests and the effect on beneficial predators and parasites. The product that has highest activity on pests may not be the best choice overall. Furthermore, growers would have a worse result if the pesticide used had poor effects on the target pest but killed most beneficial species.

One option often considered by growers who recognise the value of beneficial species is to buy commercially produced predators and parasites for liberation into their crops. This method can be successful given some very important qualifications. Firstly, the introductions (augmentation) are most successful when made early, before pest populations are too high. The introductions should be seen as introducing an early generation of beneficials into an agricultural ecosystem so that they can begin to breed and respond to pest numbers. It is rare to find situations where it would be commercially and practically possible to inundate a crop with sufficient beneficials to achieve immediate control when high numbers of pests are already present. Secondly, the environment into which beneficials are released needs to be free of pesticides (including drift) that will kill the beneficials. This may seem obvious, but reference to the results here will show that most organic pesticides are capable of killing beneficial species, and growers may not be aware of this fact.

The outcome for organic growers in Australia is that the best means of controlling pests is to ensure that beneficial species are present in crops, to use appropriate cultural control measures (eg weed control, variety selection) and if further action is needed, to choose an appropriate pesticide that will kill pests but leave the beneficials intact.

Implications

The role of beneficial species on pests is of relatively greater importance in organic agriculture than in conventional agriculture, because organic growers do not have recourse to highly potent insecticides (such as synthetic pyrethroids) with which to tackle major pest problems. However, even major (multi-national) producers of synthetic insecticides recognise the importance of bio-control agents and are now producing a range of products which offer selectivity of action. Organic growers need to be careful that they are not using more disruptive pesticides (in terms of effects on beneficial species) than conventional growers.

Control of pests in organic agriculture cannot depend primarily on pesticides. However, growers cannot just assume that sufficient numbers of beneficial species will be present in any particular crop. Growers must constantly monitor their crops and decide if the release of beneficial species, or the use of pesticides, is required. In either case, action must be taken early, and the correct species or product must be selected.

To use either selective pesticides or appropriate predators or parasites, growers need to be able to correctly identify both pests and beneficials. That means identifying all stages of these species (eggs, juveniles and adults) and not just one form. Identification guides to pests and beneficial species for particular crops are the best way to provide this information.

Recommendations

1. Growers need to know the results of pesticide testing.

Information on the effects of pesticides needs to be available to all organic growers. The results from this project are fairly straightforward, and have been summarised in the final section of the Results chapter above. The results of other testing and overseas research should also be able to be synthesised by Australian researchers for Australian growers.

2. Growers need to understand that several different tests are used to assess effects of pesticides.

When companies produce information stating that pesticides are safe to beneficial species, then the type of test needs to be stated. Having testing conducted independently (even by Government agencies) is no security that a pesticide is safe for beneficial species. It is a high priority of this project to alert growers and their Associations that the bland statements of safety to beneficials may be completely misleading.

3. Growers need to be able to identify beneficial species as well as pests.

Many identification guides to pest and beneficial species are available, but further crop-specific guides need to be provided for organic growers. As many growers already assume that beneficials are present, they need help with the identification of other common, but benign species.

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Appendix 1: Functional Diversity, Pest management & Restoration Ecology

Paper presented at the OFA Conference, Sydney 2001 by Dr Paul Horne, IPM Technologies Pty Ltd

Introduction

This paper describes the elements of agricultural ecosystems and their role in agricultural production. Rather than consider farms as crops and insects as just pests, we need to view crops as habitats for a vast range of insects and mites. Current farming practice is to grow most crops as monocultures, but even so, they are agricultural ecosystems with a range of resident and transient inhabitants. Pest species usually comprise a small percentage of the total species composition of most crops, and there are more beneficial and benign species.

Once it is accepted that there are beneficial species (predators and parasites of pests), then there is a link between pest management and conservation. Instead of farming being viewed as the opposite of conservation, farms can foster and use the natural biodiversity to help control pests and maintain populations of native species.

This concept has recently been recognised, and McIntyre *et al.* (1992) state, “The struggle to maintain biodiversity is going to be won or lost in agricultural ecosystems”.

Diversity and Pest Management

Agricultural ecosystems have for many years been monocultures and have low diversity. There can be large numbers of a very few species (often pests), and the low diversity also means low stability.

Conventionally grown crops are typically protected from insect and mite pests with a range of synthetic pesticides. Organic crops may also be treated with pesticides within the guidelines of the various associations, but in general these are less potent and shorter residual.

Where broad-spectrum insecticides are used (organic or conventional) then effects on non-target organisms means that diversity is lowered. When beneficial insects are killed, then the result is that pest control becomes even more reliant on further applications of pesticide.

Functional Diversity

“The wealth of native natural enemies and the means to incorporate them into IPM in Australia are only now coming to be appreciated” (Gillespie &New 1998). Integrated Pest Management (IPM) is a means of controlling pests without total reliance on pesticides. Instead, most control is achieved with natural enemies of pests and management methods. Pesticides are only used strategically to support these two control measures. In Australian crops grown outdoors, the biological control agents are mostly native species.

Pest Management

This paper discussed the relative role of:

- Pesticides, both organic and conventional
- Biological control
- Predators, Parasites and Pathogens
- Management techniques

These are the components of IPM strategies, and Organic farming requires IPM as much or more than conventional farming.
Pesticides are used by both organic and conventional farmers. What needs to be considered in both situations is the selectivity of the products in targeting only pests, the residual activity on pests and on beneficial species, sub-lethal effects (and not just acute mortality), and non-target mortality (including secondary poisoning from eating treated prey).

Biological Control

The best known examples of biological control are classical biological control programmes, where an exotic pest is controlled by the release of a biological control agent from the country where the pest originated. Augmentative biological control is also widely used, and this means either adding more of an existing biocontrol agent, or encouraging it by manipulating the environment or spray programme.

Mass-releases of certain commercially available species such as predatory mites and parasitic wasps are examples of augmentative biological control.

Encouraging native species is another means of augmenting biological control agents. There is an increasing role for resident native species in many cropping systems. Methods to enhance populations of beneficial species include:

- Habitat Manipulation
- Complexity associated with stability – Structure of habitat
- Rotation, Planting sequence,
- Irrigation, soil management
- Cover crops, inter-planting,
- Nectar sources

Pest species may be either native or exotic. Native pests include Heliothis (*Helicoverpa*) spp. and Lightbrown apple moth. Exotic pests include species such as *Plutella*, potato moth, and many slugs and snails.

Similarly, beneficial species can be either native or exotic. Most introduced beneficial species are parasites rather than predators, to avoid them becoming pests themselves.

Restoration Ecology

Examples were given of situations where pests became more serious as a result of changed management practices. The time taken for these situations to develop and be solved varied considerably, but all took at least one year. Examples include:

- Cicadas in coffee
- Organic vs conventional
- Conventional tillage vs conservation tillage
- Table grapes & wine grapes
- Mealybugs and mites
- Potato crops

Conclusion

- Organic farming is better placed at present to use native biodiversity to obtain better control of pests
- Primary control should be biological, supported by management and only then with pesticides
- Increasing diversity means more species to identify
- There is a real cost when misidentification of pests or beneficials occurs. Correct identification becomes more important when a diverse range of species are involved in an agricultural ecosystem.

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