

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

**DETERMINING THE EFFICACY OF  
ORGANIC INSECTICIDES AND SYNERGISTS  
AGAINST A RANGE OF  
REPRESENTATIVE INSECT AND MITE PESTS  
USING A POTTER TOWER.**

-----

**A project  
submitted in partial fulfilment  
of the requirements for the Degree  
of  
Masters of Science  
at Massey University**

**by**

**S. J. Wright**

-----

**Massey University**

**1998**

## GENERAL ABSTRACT

A variety of insecticidal formulations were examined for their efficacy against a range of insects under laboratory conditions using a Potter Tower technique.

The insecticides Yates Pyrethrum, Eco-oil, Defender, Orchex, Confidor, Agrimec, Encapsulated Pyrethrum, Encapsulated Pyrethrum and Neem, Azatin, NeemAzal, as well as a combination of the insecticides Azatin plus Eco-oil were tested at both the half as well as the full recommended field rate against a range of insect pests.

In addition, the ability to synergise natural pyrethrum by some or all of the natural compounds including sesame oil, the crystalline extract of a sesame oil crude extract, dillapiole, and the synthetic synergist PBO, in spray emulsions at a variety of rates and ratios was examined in tests against the pea aphid *Acyrtosiphon pisum*, passionvine hopper (*Scolypopa australis*), greenhouse thrip, and lightbrown apple moth.

Confidor and Yates Pyrethrum gave marked control ( i.e. mortality > 80%) of the greatest number of test species including the aphid, thrip and mealybug and two of the moth species for Confidor and all of the moth, aphid and thrip species for Yates Pyrethrum.

It is suggested that the use of the synthetic synergist PBO could be replaced by the natural synergists including dillapiole, as well as the crystalline extract of a sesame oil crude extract at the highest ratio that was tested against the pea aphid, passionvine hopper, and lightbrown apple moth. Results with greenhouse thrip and tomato fruit worm were inconclusive.

A complete summary of the results is given in abstract form for each of the three parts of this dissertation.

## ACKNOWLEDGEMENTS

I would like to thank my supervisors Prof B. Springett , and Dr I. Stringer for the help and advice that they have given me throughout this thesis.

To Melanie Grassam for her answers to my queries regarding insect rearing techniques.

Also, thanks to Dave Rogers of Hort. Research for supplying the large majority of the insects used in this report.

To Mark Hewitson for the hours of helpful word processing advice.

Most of all, to Pete de Jong and Yates New Zealand Ltd for giving me the opportunity to undertake this study, and supplying me with the insecticides and feedback required for its completion, and for funding.

## TABLE OF CONTENTS

	<b>PAGE No.</b>
General Abstract	ii
Acknowledgements	iii
<b>GENERAL INTRODUCTION</b>	<b>1</b>
<b>PART A</b>	
<b>CHAPTER</b>	<b>PAGE No.</b>
<b>1. INTRODUCTION</b>	<b>7</b>
<b>2. REVIEW OF LITERATURE</b>	<b>8</b>
2.1. INTRODUCTION	8
2.2. YATES PYRETHRUM	8
2.3. ECO-OIL	9
2.4. DEFENDER	9
2.5. ORCHEX 692	10
2.6. CONFIDOR	10
2.7. AGRIMEC	11
2.7.1. Introduction	11
2.7.2. Spectrum of activity	11
2.7.3. Mode of action	12
2.7.4. Commercial prospects	12
2.7.4.1. Effects on non-target organisms and humans	12
2.7.4.2. Development of resistant insects	12
2.7.4.3. Environmental effects	13

2.8.	ENCAPSULATED PYRETHRUM	13
2.9.	ENCAPSULATED PYRETHRUM AND NEEM	13
2.10.	INSECT GROWTH REGULATORS	13
2.10.1.	Azatin	14
2.10.2.	NeemAzal-T/S	15
<b>3.</b>	<b>MATERIALS AND METHODS</b>	<b>16</b>
3.1.	SOURCE AND ESTABLISHMENT OF TEST INSECTS	16
3.1.1.	Lightbrown Apple Moth	16
3.1.2.	Diamondback Moth	16
3.1.3.	Codling Moth	16
3.1.4.	Pea Aphid	16
3.1.5.	Greenhouse Thrip	16
3.1.6.	Predator Mite	17
3.1.7.	Obscure Mealybug	17
3.2.	LABORATORY EXPERIMENT	17
3.2.1.	Insecticide Treatment	17
3.2.2.	Bioassay Set Up for Each Test Insect Species	18
3.2.2.1.	Lightbrown Apple Moth	18
3.2.2.2.	Diamondback Moth	19
3.2.2.3.	Codling Moth	19
3.2.2.4.	Pea Aphid	19
3.2.2.5.	Greenhouse Thrip	19
3.2.2.6.	Predator Mite	20
3.2.2.7.	Obscure Mealybug	20
3.2.2.8.	I.G.Rs.	20
3.2.3.	Insecticide Application	21
3.2.4.	Mortality Assessment	22
3.2.5.	Analysis of Laboratory Results	23
<b>4.</b>	<b>RESULTS</b>	<b>25</b>
4.1.	YATES PYRETHRUM	26
4.2.	ECO-OIL	27

4.3.	DEFENDER	28
4.4.	ORCHEX 692	29
4.5.	CONFIDOR	30
4.6.	AGRIMEC	31
4.7.	ENCAPSULATED PYRETHRUM	32
4.8.	ENCAPSULATED PYRETHRUM and NEEM	33
4.9.	AZATIN and ECO-OIL	34
4.10.	AZATIN	35
4.11.	NEEMAZAL-T/S	36
<b>5.</b>	<b>DISCUSSION</b>	<b>37</b>
5.1.	YATES PYRETHRUM	38
5.2.	ECO-OIL	39
5.3.	DEFENDER	40
5.4.	ORCHEX 692	41
5.5.	CONFIDOR	41
5.6.	AGRIMEC	43
5.7.	ENCAPSULATED PYRETHRUM	44
5.8.	ENCAPSULATED PYRETHRUM and NEEM	46
5.9.	AZATIN and ECO-OIL	47
5.10.	AZATIN	48
5.11.	NEEMAZAL-T/S	51
5.12.	EVALUATION OF THE METHODOLOGY USED IN THE POTTER TOWER INSECT BIOASSAY	52
<b>6.</b>	<b>CONCLUSION</b>	<b>54</b>

## PART B

CHAPTER	PAGE No.
<b>1. INTRODUCTION</b>	<b>56</b>
<b>2. REVIEW OF LITERATURE</b>	<b>57</b>
2.1. INTRODUCTION	57
2.2. SESAME OIL	57
2.2.1. The synergistic content of cultivated sesame oil	60
2.3. DILL OIL	61
2.3.1. Dillapiole	63
2.4. PBO	64
<b>3. MATERIALS AND METHODS</b>	<b>65</b>
3.1. SOURCE AND ESTABLISHMENT OF TEST INSECTS	65
3.2. LABORATORY EXPERIMENT	65
3.2.1. Insecticide Treatment	65
3.2.2. Bioassay Set Up	69
3.2.3. Insecticide Application	69
3.2.4. Mortality Assessment	69
3.2.5. Analysis of Laboratory Results	70
<b>4. RESULTS</b>	<b>71</b>
4.1. PYRETHRUM	73
4.2. SESAME OIL	74
4.3. CRYSTALLINE EXTRACT OF SESAME OIL	75



4.4.	DILL APIOLE	76
4.5.	PIPERONYL BUTOXIDE	77
4.6.	COMBINED RESULTS OF ALL THE SPRAY COMPOSITIONS AND THEIR ASSOCIATED RATES AND RATIOS TESTED	78
<b>5.</b>	<b>DISCUSSION</b>	<b>80</b>
5.1.	SESAME OIL	80
5.2.	CRYSTALLINE EXTRACT OF SESAME OIL CRUDE EXTRACT	81
5.3.	DILLAPIOLE	83
5.4.	PBO	84
5.5.	COMPARATIVE SYNERGISTIC ABILITIES OF THE TESTED SYNERGISTS	84
5.6.	SYNERGISTIC ABILITIES OF THE NATURAL SYNERGISTS IN COMPARISON TO THE SYNTHETIC SYNERGIST PBO	86
5.7.	CONCLUSION	87

### PART C

CHAPTER	PAGE No.	
<b>1.</b>	<b>INTRODUCTION</b>	<b>91</b>
<b>2.</b>	<b>MATERIALS AND METHODS</b>	<b>92</b>
2.1.	SOURCE AND ESTABLISHMENT OF TEST INSECTS	92
	2.1.1. Passionvine hopper	92
	2.1.2. Greenhouse Thrip	92
	2.1.3. Lightbrown apple moth	92

2.1.4.	Tomato fruit worm	92
2.2.	<b>LABORATORY EXPERIMENT</b>	<b>93</b>
2.2.1.	Insecticide Treatment	93
2.2.2.	Bioassay Set Up for Each Insect Species	96
2.2.2.1.	Passionvine hopper	96
2.2.2.2.	Greenhouse Thrip	96
2.2.2.3.	Lightbrown apple moth	97
2.2.2.4.	Tomato fruit worm	97
2.2.3.	Insecticide application	97
2.2.4.	Mortality assessment	98
2.2.5.	Analysis of Laboratory Results	99
<b>3.</b>	<b>RESULTS</b>	<b>100</b>
3.1.	pyr:DA 1:5	100
3.2.	pyr:DA 1:10	101
3.3.	pyr:PBO 1:4	101
3.4.	pyr:SX 1:1	102
3.5.	pyr:SX 1:5	102
<b>4.</b>	<b>DISCUSSION AND CONCLUSIONS</b>	<b>103</b>
4.1.	pyr:DA 1:5	103
4.2.	pyr:DA 1:10	103
4.3.	pyr:PBO 1:4	104
4.4.	pyr:SX 1:1	105
4.5.	pyr:SX 1:5	105
4.6.	Natural synergists vs. PBO	106
4.7.	Conclusion	108

<b>GENERAL DISCUSSION</b>		<b>109</b>
<b>REFERENCES</b>		<b>110</b>
<b>APPENDIX 1</b>	<b>SAS programme for probit analysis</b>	<b>119</b>
<b>APPENDIX 2</b>	<b>Extraction of Sesamin, Sesamolin, and Dillapiole</b>	<b>122</b>
<b>APPENDIX 3</b>	<b>SAS programme for probit analysis</b>	<b>131</b>

# LIST OF TABLES

## PART A

		page no.
<b>Table 1.</b>	The insecticides and rates used for treating each insect species.	18
<b>Table 2.</b>	The mortality criterion for each species and its lifecycle stage tested.	23
<b>Table 3.</b>	Insect mortality values for Yates Pyrethrum.	26
<b>Table 4.</b>	Insect mortality values for Eco-oil.	27
<b>Table 5.</b>	Insect mortality values for Defender.	28
<b>Table 6.</b>	Insect mortality values for Orchex 692.	29
<b>Table 7.</b>	Insect mortality values for Confidor.	30
<b>Table 8.</b>	Insect mortality values for Agrimec.	31
<b>Table 9.</b>	Insect mortality values for Encapsulated Pyrethrum.	32
<b>Table 10.</b>	Insect mortality values for Encapsulated Pyrethrum and Neem.	33
<b>Table 11.</b>	Insect mortality values for Azatin and Eco-oil.	34
<b>Table 12.</b>	Insect mortality values for Azatin.	35
<b>Table 13.</b>	Insect mortality values for Neemazal-T/S.	36
<b>Table 14.</b>	Efficacy categories for insect mortality values.	37
<b>Table 15.</b>	Insect mortality values for given species and rates for Eco-oil; Azatin; and Azatin plus Eco-oil at 48 hours.	48

## PART B

<b>Table 1.</b>	The spray compositions, ratios of pyrethrum:synergist and application rates tested.	68
<b>Table 2.</b>	Observed mortality values for pyrethrum only spray applications	73
<b>Table 3.</b>	Observed mortality values for pyrethrum plus sesame oil spray applications.	74
<b>Table 4.</b>	Observed mortality values for pyrethrum plus the crystalline extract of sesame oil crude extract spray applications.	75
<b>Table 5.</b>	Observed mortality values for pyrethrum plus dillapiole spray applications.	76
<b>Table 6.</b>	Observed mortality values for pyrethrum plus PBO spray applications.	77
<b>Table 7.</b>	Estimated L.C.50's and L.C.95's and their associated fiducial limits and degrees of synergism for each spray application.	78

## PART C

<b>Table 1.</b>	The spray compositions, ratios of pyrethrum:synergist, and application rates tested.	95
<b>Table 2.</b>	Insect mortality values for pyr:DA 1:5	100
<b>Table 3.</b>	Insect mortality values for pyr:DA 1:10	101
<b>Table 4.</b>	Insect mortality values for pyr:PBO 1:4	101
<b>Table 5.</b>	Insect mortality values for pyr: SX 1:1	102
<b>Table 6.</b>	Insect mortality values for pyr: SX 1:5	102

## LIST OF PLATES

### PART A

- Plate 1.** The Potter tower. 24

## LIST OF FIGURES

### PART B

- Figure 1.** Observed mortality values of the pea aphid to spray applications of pyrethrum containing the crystalline extract of sesame oil, PBO and dillapiole. 89
- Figure 2.** Observed mortality values of the pea aphid to spray applications of pyrethrum containing PBO, sesame oil, as well as to spray applications of pyrethrum alone. 90

## GENERAL INTRODUCTION

With the increasing emphasis by consumers and agricultural export markets, particularly in developed countries, towards sustainability, environmental agriculture, and organic production, there is a growing recognition that if New Zealand is to retain or expand access to these markets then it must respond to this demand.

Agricultural policy is being increasingly driven by these sociopolitical forces (Hall et al 1989) and in response to this pressure the adoption of organic practices and values in new farming systems are emerging with more sustainable methods and growing markets (McCrae et al 1989).

Although there is little consensus as to what sustainability is precisely, and a myriad of definitions have been proposed, in the wider sense it clearly involves biology, ecology, economics, and sociocultural and political considerations (Singh & Thornton 1992).

World Bank economist Herman Daly, (Daly 1991) suggested three conditions that would have to be met by society's material and energy throughputs in order to be physically sustainable. Firstly its rates of use of renewable resources do not exceed their rates of regeneration, secondly its rates of use of nonrenewable resources do not exceed the rate at which sustainable renewable resources are developed, thirdly its rates of pollution emission do not exceed the assimilative capacity of the environment.

MAF New Zealand (1994) defines sustainability in general terms as the ability of a system to endure, by maintaining the resource base, and the absence of unacceptable effects on people or the environment.

An alternative and defensible term of sustainability is sustainable development. The most widely adopted definition of sustainable development, which is the key concept of the Brundtland Report (1987), is defined as 'development that meets the needs of the present without compromising the ability of the future generations to meet their own needs'.

Included in its strategy for sustainable food security, the Brundtland Report states that 'Pest control must be based increasingly on the use of natural methods....The legislative, policy, and research capacity for advancing non-chemical and low-chemical strategies must be established and sustained'. Further, included in its strategy for sustainable industrial development, the Brundtland Report states that 'The chemical producer and user industries...should bear the responsibility for ensuring that their products meet the highest standards of safety, have the fewest adverse side effects on health and the environment, and are handled with appropriate care by workers and users'.

Organic farming is therefore one of several systems, other than Integrated Pest Management, that can move New Zealand farming practices towards the goal of sustainability by the use of a range of primarily biological (as opposed to synthetic chemical inputs) strategies that produces a commodity free of conventional chemical use, while maintaining soil fertility and plant and animal health.

While some writers such as McCrae et al (1990) have pointed out that most organic farmers are only part of the way along a continuum between input dependent farming (conventional) and sustainable systems, others view sustainability differently. For instance Fisher (1989) from an economical viewpoint believes that a system using some



chemical inputs can be more sustainable than a strictly organic system as it is more able to endure than a system that does not use any chemical inputs.

Never the less, the use of organic pesticides is a valuable tool in the development of a sustainable agriculture, whether it is used by organic farming systems or more conventional systems.

Pyrethrum is the only chemical compound, other than soaps and oils and *Bacillus thuringiensis* which is accredited by the organic production standards in New Zealand and is the most dependable of these chemicals (Epenhuijsen et al 1992).

However, the most frequently used pyrethrum synergist at present, piperonyl butoxide (PBO) is synthetic (Wachs 1949) and non-organic.

As the ability of a synergist to be “environmentally friendly” or organic is now becoming more desirable with changing consumer attitudes (Hall et al 1989). There is a growing need for their synergists to be organic also, even though they may be less cost effective than the alternative synthetic synergists.

The widely accepted definition of a pesticide synergist was described by Matsamura (1985) as “ compounds that greatly enhance the toxicity of an insecticide, although they are usually practically non-toxic by themselves”.

Originally sought as a means to increase the insecticidal activity of pyrethrum in order to conserve it, today pyrethroid synergists are predominantly used to increase the cost

efficiency of pest control by pyrethroids (Brown 1971; Yamamoto 1973; Bond et al 1973), by reducing the concentration of toxicant necessary to achieve a desired mortality when it is combined with the synergist.

The history of pyrethroid synergists stretches back to their origins in the first World War.

In 1940, the synergistic action of sesame oil was first discovered by Eagleson, its active components each having the methylenedioxyphenyl (MDP) moiety.

Recognition of the importance of the MDP moiety for synergism led to the testing for synergistic potency for hundreds of MDP compounds that were synthesised, or isolated from natural sources and is still continuing to a somewhat lesser extent today.

PBO, the first truly effective commercially viable synergist was patented in 1949 and as is previously mentioned it is still a requirement in most pyrethrum insecticides. PBO is an MDP synergist.

Today it is accepted that synergists primarily increase the toxicity of insecticides by inhibiting their metabolism (Casida 1970; Georghiou 1983; Sun & Johnson 1972). In particular, the synergistic effect of MDP synergists has been related to the greater competitive ability of these synergists ( in comparison to the chemical insecticide) to form metabolic complexes with cytochrome P450 (Perry & Buckner 1970), as well as their production of adducts which inhibit metabolism of other substrates (Werringloer & Estabrook 1979), and thus inhibiting the oxidative metabolism of the insecticide by the mixed function oxidase system (mfo) of microsomes. In other words, the synergists act

as alternative substrates of metabolism, sparing the chemical insecticide from detoxification. Although it is known that MDP synergists are metabolised by oxidation on various sites on their long aliphatic side chains, it is still unclear why the synergists are competitively superior to the insecticide in their ability to form P450 metabolic complexes. This may be due to either improved fit on the active site of the pyrethroid metabolising enzymes or to the availability of the additional sites on the synergists.

This study is divided into three separate parts and although they each have three different aims they are somewhat interrelated.

The aim of the first study was to undertake an assessment on a range of insect species of the efficacy of a range of pesticides, the majority of which are 'soft' pesticides i.e. are natural products which offer lower levels of impact on the environment than the alternative conventional synthetic chemicals. Some of these pesticides have not been released by pesticide companies in New Zealand. Three of these pesticides contain the toxicant natural pyrethrum which is examined more closely in the remaining two parts of this thesis.

Secondly, an assessment of the efficacy of the natural oils sesame and dill, and their extracts, as synergists for natural pyrethrum against the pea aphid *Acyrtosiphon pisum* were examined in comparison to the relative efficacy of the synthetic natural pyrethrum synergist piperonyl butoxide (PBO).

Thirdly, as both toxicity and the degree of synergism of synergists is specific to an insect species, the efficacy of the natural synergists from Part B were examined against a wider range of insect species.

The last two parts were undertaken with the ultimate aim of developing an effective natural pyrethrum product in New Zealand which contains an organic synergist.