

**The Seasonal Abundance and Impact of Predatory Arthropods
on *Helicoverpa* Species in Australian Cotton Fields**

by

John Newton Stanley

B.Rur. Sc. (University of New England)

A thesis submitted for the degree of

Doctor of Philosophy

from the

**University of New England
Department of Agronomy and Soil Science**

September 1997

Many Thanks to the Following:

Associate Professor Peter Gregg, who, as sole supervisor, provided a broad field of opportunities, as well as cotton, for the discovery of entomological things. Thank you for your guidance and support.

Mr. Richard Browne, of Auscott Pty. Ltd., and Ben and Dave Coulton, of Coulton Farming Ltd. for allowing me access to their crops and for adjusting their cultural practices to accommodate experimental designs. Particular thanks to Terry Haynes (Senior Agronomist; Auscott Pty. Ltd. Moree) for discussions on pest management and generously supplying assistance at critical times.

The taxonomists who identified material for the insect survey.

Mr. L. Bauer	(Thysanoptera)
Dr. A. Calder	(Coleoptera)
Dr. M. Carver	(Homoptera and Trichogrammatidae)
Dr. D. H. Colless	(Diptera)
Dr. M. J. Fletcher	(Cicadellidae)
Dr. M. R. Gray	(Aracnida)
Dr. M. B. Malipatil	(Hemiptera)
Dr. I. D. Naumann	(Hymenoptera)
Dr. T. R. New	(Neuroptera)
Dr. T. A. Weir	(Coleoptera)

The people who provided technical assistance:

Holly Ainslie, Dr. Steven Asante, Doreen Beness, Laura Bennett, Samantha Browne, Dr. Mark Coombs, Peter Foreman, Jacqueline Prudon, Sally Schwitzer, Kelly Stanley, Anita Stevenson, Donald Wheatley, and Richard Willis.

Dr. Steven Trowell for guidance using serological methods and to Dr. Anne Bourne for her statistical significance.

Mr. Robert Gregg for accomodating my family at 'Tyreel' whilst sampling in Moree.

Special thanks to Lindsay Tuart for insights on cotton agronomy and insect prevalence especially during the early stages of this study.

My salary was provided by an Australian Post Graduate Award and the experimental work was funded by the Cotton Research and Development Council (C.R.D.C.).

I dedicate this thesis to my family

Kelly

Benjamin & Daniel

Abstract

The problems of assessing the predatory impact of one species of arthropod upon another have been addressed for over 50 years, and still remain largely unsolved. The literature is reviewed and principles derived from it are applied to the case of generalist arthropod predators on *Helicoverpa* spp. (Lepidoptera: Noctuidae) in Australian cotton. Theoretical aspects discussed include the validity of functional and numerical responses as indicators of field predation rates and some current ideas on the survival behaviour of predatory insects, along with their implications for the desirable properties of biological control agents.

The production of cotton in Australia relies heavily on the use of broad spectrum insecticides to control two key pests, *Helicoverpa punctigera* (Wallengren) and *Helicoverpa armigera* (Hübner). The potential loss of two of these insecticide groups, the synthetic pyrethroids and endosulfan, because of resistance in *H. armigera* and environmental concerns respectively, has rekindled the search for ways of utilising alternative sources of pest mortality. An appealing possibility is that endemic predators and parasites can maintain pest populations below economic thresholds. However the extensive use of insecticides throughout the history of Australian cotton production means that the potential of endemic natural enemies to control *Helicoverpa* spp. is not normally realised.

Trials using realistic field sizes were being conducted by Auscott Pty. Ltd. (a large corporate farming group at 'Midkin', near Moree, N.S.W.) to broadly assess the prospects of growing cotton without using endosulfan and synthetic pyrethroids. This presented an opportunity to examine the predatory impact of arthropod populations which could reasonably be expected to increase under these 'softer' insecticide strategies. Pioneering efforts in 1993 by Coulton Farming (based at Goondiwindi and North Star, N.S.W.) to grow organic cotton provided further opportunities to examine predator populations under reduced insecticides practices in cotton fields isolated from regional insecticide drift.

The experimental sections of this thesis report the abundance of all the arthropods, especially predators, collected in suction samples from the different treatments used at these farms. The treatments included: no insecticides, organically certified treatments, perceived softer insecticide options (essentially avoiding endosulfan, synthetic pyrethroids and organophosphates) and conventional broad spectrum insecticides.

Surveys were conducted using visual methods and a variety of suction samplers, the main one being a backpack-styled suction sampler similar to the D-vac designed by Dietrick (1961). The method of sampling was different from those previously reported in the literature, and from those used in the Australian cotton industry at the time of the study. Preliminary studies compared the effectiveness of different suction sampling methods and this is discussed along with an overview of sampling methods previously used for the evaluation of predatory impact. A large D-vac styled sampler collected many more arthropods (especially towards the end of the season) than a smaller one which was in common use in the cotton industry. The diurnal patterns of catchability using suction samplers were traced over three 24 hour experiments. The effect of sampling from higher compared to lower in the cotton crop canopy was briefly investigated and established that sampling which concentrated on the terminal sections of plants may fail to indicate the presence of considerable populations of predatory species.

Attempts were made to establish the impact of predators on *Helicoverpa* spp. by identifying spatial correlations between these arthropods. Higher numbers of predators, as species or groups, were present where overall prey was more abundant. However, there was no clear evidence that these areas corresponded to lower *Helicoverpa* spp. density. Furthermore, no particular predatory species, except perhaps *Geocoris* spp., appeared to specialise on this prey. In all cases the abundance of predators failed to explain enough of the variation in *Helicoverpa* spp. density to suggest a controlling impact.

Chlorfluazuron and thiodicarb were included in soft option insecticide treatments but were found to be not as soft on beneficial arthropods as expected. The converse was found for endosulfan. The regional use of insecticides appeared to cause a general decline in predator abundance throughout the latter half of the cotton growing season, even where fields were not directly treated with insecticide. The reduction in local predator source areas, insecticide drift and the movements of predators into treated fields are possible explanations.

Laboratory prey consumption trials were conducted which showed considerable potential for predator control of *Helicoverpa* spp. However field cage studies provided considerably lower and probably more realistic estimates of prey consumption. For the predator species tested, these experiments showed a very limited impact on *Helicoverpa* spp. at the commonly experienced densities of these predators and pests. These trials revealed the

difficulties in establishing real field predation rates on pests of relatively low density, especially when abundant alternative prey were present. The lessons learned, especially regarding the evaluation and interpretation of predator functional responses, are discussed.

Brief introductory experiments were conducted, using existing antibodies, to develop a serological (ELISA) protocol to identify predators which had fed on *Helicoverpa* spp. Predation was detectable in immediately prepared, fresh samples of a predatory beetle, *Dicranolaius bellulus* (Guérin-Meneville). However samples which had been snap frozen in liquid air produced false positives by disrupting the specificity of the biotin-avidin link commonly used in ELISA procedures.

The overall conclusion reached from all these studies is that the impact of predators on *Helicoverpa* spp. in cotton, as it is currently produced in Australia, is uncertain and generally low. However, recent advances in the management of *Helicoverpa* spp. are compatible with the conservation of predators. This should reduce the reliance on broad spectrum insecticides, thus permitting a more effective role for predators.

TABLE OF CONTENTS

Title.....	i
Declaration.....	ii
Acknowledgements.....	iii
Dedication.....	iv
Abstract.....	v
1. PEST CONTROL BY ARTHROPOD PREDATORS	1
1.1 INTRODUCTION.....	1
1.2 THE GREAT DEBATE OVER POPULATION REGULATION	2
1.2.1 <i>Importance of Regulation to Pest Control</i>	5
1.3 THE IMPACT OF PREDATORS	5
1.3.1 <i>General Lack of Conclusive Evidence</i>	5
1.3.2 <i>Measurement of Predation</i>	7
1.4 CLASSICAL FUNCTIONAL & NUMERICAL RESPONSE THEORY.....	9
1.4.1 <i>Functional Responses</i>	9
1.4.2 <i>Reproductive Numerical Responses</i>	10
1.4.3 <i>Difficulties with Measurement and Interpretation</i>	11
1.5 BEHAVIOUR FOR SURVIVAL, AND THE IMPLICATIONS FOR BIOLOGICAL CONTROL	15
1.6 ARE PREDATORS GOOD BIOLOGICAL CONTROL AGENTS?.....	16
1.6.1 <i>Survival of Predators in Agricultural Systems</i>	16
1.7 CONCLUSION	17
2. THE PROSPECT OF CONTROLLING <i>HELICOVERPA</i> SPP. BY PREDATORS IN AUSTRALIAN COTTON CROPS	19
2.1 INTRODUCTION.....	19
2.2 THE AUSTRALIAN COTTON INDUSTRY	19
2.3 <i>HELICOVERPA</i> SPP. AS KEY PESTS OF AUSTRALIAN COTTON	20
2.3.1 <i>Helicoverpa Ecology and Control in Australian Cotton</i>	22
2.3.2 <i>Non-Chemical Alternatives for Pest Management in Cotton</i>	24
2.4 HOW CAN PREDATORS BE INCLUDED IN CONTROL PROGRAMMES ?.....	27
2.5 PROSPECTS FOR CONTROLLING <i>HELICOVERPA</i> SPP. WITH PREDATORS	29
2.5.1 <i>International Comparisons</i>	29
2.5.2 <i>Which Predators Consume Helicoverpa spp.?</i>	37
2.5.3 <i>Measurements of Predation Rates on Helicoverpa spp.</i>	37
2.5.4 <i>Prospects For Improving Predator Efficiency</i>	43
2.5.5 <i>How Predators Might Be Incorporated into IPM</i>	44
2.6 CONCLUSIONS	45
3. GENERAL MATERIALS AND METHODS:	47
3.1 INTRODUCTION.....	47
3.2 THE STUDY SITES.....	48
3.2.1 <i>Midkin 1992/3</i>	49
3.2.2 <i>Midkin 1993/4</i>	50
3.2.3 <i>Alcheringa 1993/4</i>	51
3.2.4 <i>Wilby 1993/4</i>	52
3.3 SAMPLING METHODS	53
3.3.1 <i>Visual Counts</i>	53
3.3.2 <i>Small Electric Suction Sampler ("Elecvac")</i>	53
3.3.3 <i>Large Petrol Suction Sampler ("Bigvac")</i>	54
3.3.4 <i>Small Petrol Suction Sampler ("Macvac")</i>	54
3.3.5 <i>Arthropod Sample Processing</i>	55
3.4 ARTHROPOD SPECIES	56
3.4.1 <i>Specimen Identification</i>	56
3.4.2 <i>Species Collected</i>	56

4. SUCTION SAMPLING OF ARTHROPODS IN COTTON CROPS	63
4.1 INTRODUCTION.....	63
4.2 SAMPLING ARTHROPODS ON COTTON.....	65
4.2.1 Absolute and Relative Sampling Methods.....	65
4.2.2 How D-Vac® Suction Samples are Collected.....	65
4.2.3 The Sampling Efficiency of D-Vac® Suction Samples.....	66
4.2.4 The Possibility of Improving D-Vac® Sample Efficiency.....	72
4.2.5 Why Persist with Suction Sampling In This Thesis Project?.....	73
4.3 THE EFFECT OF SUCTION SAMPLING METHOD ON THE SIZE AND DIVERSITY OF THE SAMPLE.....	74
4.3.1 Introduction and Aim.....	74
4.3.2 Methods.....	75
4.3.3 Results and Discussion.....	75
4.4 THE SEASONAL INFLUENCE ON THE RELATIVE SAMPLING EFFICIENCY OF SUCTION SAMPLING.....	78
4.4.1 Aim and Methods.....	78
4.4.2 Results and Discussion:.....	78
4.5 SAMPLING FROM THE TOP OR BOTTOM OF THE CANOPY.....	80
4.5.1 Aim.....	80
4.5.2 Methods.....	81
4.5.3 Results and Discussion.....	81
4.6 DIURNAL EFFECTS ON SUCTION CATCH.....	83
4.6.1 Introduction and Aim.....	83
4.6.2 Methods.....	83
4.6.3 Results and Discussion.....	84
4.7 EXPERIMENT 5: REPEAT SUCTION VALIDATION TRIALS.....	88
4.7.1 Introduction and Aim.....	88
4.7.2 Methods.....	88
4.7.3 Results and Discussion:.....	88
4.8 GENERAL CONCLUSIONS.....	94
5. FIELD SURVEY OF THE SEASONAL ABUNDANCE OF PREDATORS, AND THE EFFECTS OF INSECTICIDES, IN DIFFERENT PEST MANAGEMENT REGIMES	95
5.1 INTRODUCTION.....	95
5.2 MATERIALS AND METHODS.....	96
5.3 RESULTS AND DISCUSSION.....	104
5.3.1 <i>Campylomma</i> spp. (including <i>Campylomma liebkechti</i> , the Apple Dimpling Bug).....	108
5.3.2 <i>Dicranolaius bellulus</i> (The Red and Blue Beetle).....	109
5.3.3 <i>Creontiades dilutus</i> (Green Mirid).....	118
5.3.4 <i>Nabis kinbergii</i> (Pacific Damsel Bug).....	121
5.3.5 <i>Coccinella transversalis</i> (Transverse Ladybird).....	125
5.3.6 <i>Diomus notescens</i> (Two spotted ladybird).....	128
5.3.7 <i>Geocoris</i> spp.....	131
5.3.8 <i>Orius</i> Spp. (Minute Pirate Bugs).....	134
5.3.9 <i>Germalus</i> sp.....	137
5.3.10 <i>Oechalia schellenbergii</i>	138
5.3.11 <i>Mallada signata</i> (Green lacewing).....	139
5.3.12 Spiders.....	140
5.3.13 Formicidae (ants).....	146
5.3.14 Total Predators.....	149
5.4 GENERAL PREDATOR CONCLUSIONS.....	153
5.5 ABUNDANT ALTERNATIVE PREY.....	156
5.5.1 Cicadellids and related insects.....	157
5.5.2 Thysanoptera (thrips):.....	160
5.6 GENERAL CONCLUSIONS:.....	160

6. THE DISTRIBUTION AND ABUNDANCE OF PREDATORS RELATIVE TO <i>HELICOVERPA</i> SPP. AND ALTERNATIVE PREY.....	165
6.1 INTRODUCTION.....	165
6.2 THE RELATIVE ABUNDANCE OF PREDATORS AND <i>HELICOVERPA</i> SPP.	165
6.3 POPULATION STUDIES TO IDENTIFY THE IMPACT OF PREDATORS.....	167
6.3.1 <i>Approaches of Limited Value for Studying Predator Effectiveness in Cotton</i>	170
6.4 SPATIAL POPULATION COMPARISONS	174
6.4.1 <i>Materials and Methods</i>	176
6.4.2 <i>Results and Discussion</i>	179
6.4.3 <i>Time Series Analysis</i>	183
6.5 GRADIENTS OF ARTHROPOD ABUNDANCE IN COTTON FIELDS	186
6.5.1 <i>Introduction</i>	186
6.5.2 <i>Methods</i>	187
6.5.3 <i>Results and Discussion</i>	188
7. PREDATION BY GENERALIST PREDATORS ON <i>HELICOVERPA</i> SPP. IN LABORATORY AND FIELD CAGE EXPERIMENTS.....	198
7.1 INTRODUCTION.....	198
7.2 LABORATORY CONSUMPTION TRIAL OF <i>HELICOVERPA</i> SPP. EGGS BY ADULT <i>DICRANOLAIUS BELLULUS</i>	200
7.2.1 <i>Introduction</i>	200
7.2.2 <i>Materials and Methods</i>	200
7.2.3 <i>Results and Discussion</i>	202
7.3 FIELD CAGE EXPERIMENT 1: THE PREDATION OF <i>H. PUNCTIGERA</i> EGGS BY ADULT <i>D. BELLULUS</i>	204
7.3.1 <i>Introduction and Aim</i>	204
7.3.2 <i>Materials and Methods</i>	204
7.3.3 <i>Results and Discussion</i>	208
7.4 FIELD CAGE EXPERIMENT 2: THE PREDATION OF <i>H. PUNCTIGERA</i> LARVAE BY <i>DICRANOLAIUS BELLULUS</i> ADULTS AND <i>MALLADA SIGNATA</i> LARVAE.....	213
7.4.1 <i>Introduction</i>	213
7.4.2 <i>Materials and Methods</i>	213
7.4.3 <i>Results and Discussion</i>	214
7.5 FIELD CAGE EXPERIMENT 3: PREDATION OF <i>HELICOVERPA PUNCTIGERA</i> LARVAE BY ENDEMIC PREDATORS IN THE PRESENCE OF ALTERNATIVE PREY.....	216
7.5.1 <i>Introduction</i>	216
7.5.2 <i>Materials and Methods</i>	216
7.5.3 <i>Results and Discussion</i>	217
7.5.4 <i>Overall Conclusions for the Field Cage Series of Experiments</i>	218
8. SEROLOGICAL METHODS FOR ASSESSING THE PREDATION OF <i>HELICOVERPA</i> SPP. BY <i>DICRANOLAIUS BELLULUS</i>.....	222
8.1 DETECTING PREY IN THE GUT CONTENTS OF PREDATORS.....	222
8.1.1 <i>Introduction</i>	222
8.1.2 <i>Radiotracers</i>	223
8.1.3 <i>Immunological Assays</i>	224
8.2 SEROLOGICAL EXPERIMENTS	228
8.2.1 <i>Introduction</i>	228
8.2.2 <i>General Methods</i>	228
8.3 EXPERIMENT 1: USING ANTIBODY-B TO DETECT <i>HELICOVERPA ARMIGERA</i> IN THE GUT CONTENTS OF <i>DICRANOLAIUS BELLULUS</i>	230
8.3.1 <i>Aim</i>	230
8.3.2 <i>Methods</i>	231
8.4 EXPERIMENT 2. USING ANTIBODY-B TO DETECT <i>HELICOVERPA</i> SPP. IN FIELD COLLECTED <i>DICRANOLAIUS BELLULUS</i>	232
8.4.1 <i>Introduction</i>	232
8.4.2 <i>Methods</i>	233
8.4.3 <i>Results and Conclusions</i>	233

8.5 EXPERIMENT 3: USING ANTIBODY-70 TO DETECT <i>HELICOVERPA ARMIGERA</i> IN THE GUT CONTENTS OF <i>DICRANOLAIUS BELLULUS</i>	234
8.5.1 <i>Introduction and Aim</i>	234
8.5.2 <i>Methods</i>	234
8.5.3 <i>Results and Conclusions</i>	234
8.6 EXPERIMENT 4: TESTING FOR ENDOGENOUS COLOUR REACTIONS.....	235
8.6.1 <i>Introduction and Aim</i>	235
8.6.2 <i>Methods</i>	235
8.6.3 <i>Results and Discussion</i>	235
8.7 EXPERIMENT 5: BIOTIN-LIKE BINDING SITES IN FROZEN BEETLE SAMPLES.....	236
8.7.1 <i>Aim & Methods</i>	236
8.7.2 <i>Results and Overall Conclusions</i>	236
8.8 THE POTENTIAL FOR SEROLOGICAL METHODS FOR ASSESSING PREDATORY IMPACT ON <i>HELICOVERPA</i> SPP.....	236
9. CONCLUSIONS AND RELEVANCE TO <i>HELICOVERPA</i> SPP. MANAGEMENT IN AUSTRALIAN COTTON.....	238
9.1 SUCTION SAMPLING.....	238
9.2 CLASSICAL PREDATION MEASUREMENTS.....	238
9.3 SEROLOGICAL ANALYSIS.....	239
9.4 PREDATOR ABUNDANCE.....	239
9.5 PREDATOR IMPACT.....	240
9.6 PREDATORS IN INTEGRATED <i>HELICOVERPA</i> SPP. MANAGEMENT.....	241
9.7 THE FUTURE.....	242
APPENDIX	
Appendix 5.1 Ranking Predator Abundance.....	244
Appendix 5.5 Meteorological Data.....	254
Appendix 5.6 Sources of Insecticides.....	256
Appendix 7.1 Comparison of Canopy Temperature Inside and Outside Field Cages.....	257
Appendix 7.2 The Statistical Analysis of the Effect of Predators on Aphid Abundance.....	259
Appendix 7.3 The Life Cycle and Rearing Methods for <i>Dicranolaius bellulus</i>	260
Appendix 7.4 Field Cages for Predation Studies on Cotton.....	265
BIBLIOGRAPHY.....	269