

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.

**Disinfestation of apple leaf-curling midge, *Dasineura mali*
(Diptera: Cecidomyiidae) on post-harvest apple fruits
by ultraviolet-C radiation**

**A thesis presented in partial fulfilment of the requirements for the
degree of
Master of AgriScience
in
Horticulture
at Massey University, Palmerston North,
New Zealand**



Ding YUAN

2014

ABSTRACT

Apple leaf-curling midge (*Dasineura mali* Kieffer) (ALCM) is considered as an important quarantine pest of apple due to fresh fruit contamination by pupal cocoons. To meet the quarantine regulations of export markets and the expectations of customers, a series of non-chemical methods have been investigated for the potential to be applied to control insect pests. One approach, ultraviolet-C (UV-C) radiation, offers potential as a new disinfestation technique. However, the disinfestation effects of UV-C radiation in the control of ALCM have not been investigated previously.

To investigate the disinfestation effect of UV-C radiation, two individual experiments were conducted. Apple fruit-attached and non-fruit attached cocoons of ALCM were treated with a series of UV-C radiation doses, and then maintained in temperature-controlled (daily mean temperature around 20 °C) dark conditions. For non-fruit attached cocoons, the groups treated with UV-C radiation had significantly higher mortality rates than that of the control groups. For fruit attached cocoons, although the sample size was small, results indicated that cocoons treated with 20 mins, which was the most prolonged UV-C radiation treatment, exhibited the highest mortality rate. The insignificant mortality rate of cocooned larvae when comparing those groups treated with lower UV-C doses and control groups suggests that attachment of cocoons to the apple calyx may be a significant factor in limiting the effect of UV-C for the control of ALCM. To obtain understanding of the effects of UV-C radiation on the potential fecundity of female ALCM, a third experiment was conducted, where adult insects were reared following UV-C treatment of cocoons as before, and egg numbers carried by newly emerged adult females were assessed. Interestingly, although the difference in the egg quantity of female adult ALCM between treatments was not significant, it revealed that the UV-C treated group had a potential higher egg capacity with increased body size than the control group. It is possible that the short duration of UV-C radiation treatments might lead to increased egg capacity of female ALCM, and these effects are worthy of future investigation. Equally, the possibilities to provide greatly increased UV-C doses to potentially kill ALCM cocooned larvae during apple processing should be explored further.

ACKNOWLEDGEMENTS

I would like to thank Pipfruit New Zealand Incorporate (PNZI), PNZI Technical Manager Dr Mike Butcher, and Callaghan Innovation for sponsoring my project with a CAPEDU Scholarship. Callaghan Innovation is committed to help businesses be more innovative and derive greater returns on that innovation. Callaghan Innovation Funding is providing support for research students to work within R&D active business. I know this research is arguably very valuable to the apple industry, and this is one of the main purposes of the Callaghan Innovation Funding, therefore, I feel we have both gained, and I thank for your continuing interest and support.

I am deeply indebted to my chief supervisor Dr. Jason Wargent for his dedicated help, constructive advice, encouragement and guidance throughout this project. Jason always enlightened my thoughts and broadened my views. I also thank Jason for his dedication and time on reading and evaluating my thesis from beginning to final drafts.

My special gratitude also goes to Dr. X.Z. He for his devoted instruction and invaluable advice in the experimental conduction and statistical analysis. And thanks to Prof. Qiao Wang for his advice, support and encouragement.

I am very grateful to Gayani Gamage and Kay Sinclair for the arrangement of laboratory facilities throughout my research. Thanks to Plant Growth Unit in Massey University for the use of the orchard to conduct the research.

To all the friends and staff members in the Horticulture group, especially Eduardo Antonio Sandoval Cruz, Lulu He, and Denise Stewart, you always provided support and encouragement.

Finally, I owe so much to my dear Dad, Mum and sister. My endless gratitude and thanks to you for the love, support, and encouragement that you have continually given over the years.

TABLE OF CONTENTS

ABSTRACT	i
ACKNOWLEDGEMENTS	ii
TABLE OF CONTENTS	iii
LIST OF TABLES	v
LIST OF FIGURES	vi
CHAPTER 1: INTRODUCTION	1
1.1 New Zealand apple industry	1
1.2 Apple leaf-curling midge.....	3
1.3 Impact of apple leaf-curling midge	6
1.4 Apple leaf-curling midge management	8
1.5 Ultraviolet-C radiation as a non-chemical method.....	9
1.6 Project aims and objectives	11
CHAPTER 2: UV-C TREATMENT OF NON-FRUIT ATTACHED APPLE LEAF- CURLING MIDGE	13
2.1 Introduction	13
2.2 Materials and methods.....	14
2.2.1 Site description	14
2.2.2 Materials preparation	14
2.2.3 Data collection and analysis	15
2.3 Results	16
2.3.1 Mortality of ALCM in the first dissection	17
2.3.2 Mortality of ALCM in the second dissection	20
2.3.3 Mortality of ALCM in the final dissection	22
2.3.4 Total mortality of non-fruit attached ALCM.....	24
2.3.5 Emergence patterns of ALCM and <i>Platygaster demades</i>	26
2.3.6 Developmental duration of ALCM and <i>Platygaster demades</i>	27
2.4 Discussion	28
CHAPTER 3: UV-C TREATMENT OF FRUIT ATTACHED APPLE LEAF- CURLING MIDGE	32
3.1 Introduction	32
3.2 Materials and methods.....	33
3.2.1 Site description	33

3.2.2 Materials preparation	33
3.2.3 Data collection and analysis	35
3.3 Results	35
3.3.1 Total mortality of fruit attached ALCM	36
3.3.2 Proportion of ALCM larvae.....	38
3.3.3 Postharvest quality of apple fruit	39
3.4 Discussion	39
CHAPTER 4: THE EFFECT OF UV-C RADIATION ON THE EGG LOAD OF APPLE LEAF-CURLING MIDGE	42
4.1 Introduction	42
4.2 Materials and methods.....	43
4.2.1 Site description	43
4.2.2 Materials preparation	43
4.2.3 Data collection and analysis	44
4.3 Results	45
4.3.1 Body size of female ALCM.....	45
4.3.2 Egg load	45
4.3.3 Egg load of female ALCM in relation to body size.....	46
4.4 Discussion	47
CHAPTER 5: CONCLUSION.....	50
Summary of key findings	50
Future research	51
REFERENCES.....	53
APPENDICES	61
APPENDIX I.....	61
APPENDIX II.....	64
APPENDIX III	66

LIST OF TABLES

Table 2. 1	The dose of each UV-C radiation treatment in relation to the exposure time applied in the experiment.....	14
Table 2. 2	The total numbers of ALCM adults and <i>P. demades</i> adults emerged and the emergence rates	26
Table 3. 1	The dose of each UV-C radiation treatment in relation to the exposure time applied in the experiment.....	34
Table 3. 2	Average apple fruit firmness tested by Fruit Pressure Tester (kg)....	39
Table 4. 1	The dose of each UV-C radiation treatment in relation to the exposure time applied in the experiment.....	44
Table 4. 2	The body sizes of female ALCM emerged in UV-C treated and control groups. Average body length and width values are \pm S.E.....	45

LIST OF FIGURES

Figure 1. 1	New Zealand apple exports by cultivars as percentage in weight by 2011.....	1
Figure 1. 2	Life cycle of ALCM: eggs (A), larvae (B), pupa (C) and female adult (D) (Courtesy of X.Z. He).....	4
Figure 1. 3	Apple fruit contamination by ALCM cocoon in the calyx (Courtesy of X.Z. He).....	5
Figure 1. 4	Curled growing apple terminal leaves infected by ALCM larvae.....	6
Figure 2. 1	The mean (\pm S.E.) total mortality of ALCM larvae (A), parasitized ALCM larvae (B), and unparasitized ALCM larvae (C) in the first dissection, respectively. Columns with the same letters are not significantly different ($P > 0.05$).....	19
Figure 2. 2	The mean (\pm S.E.) total mortality of ALCM larvae (A), parasitized ALCM larvae (B), and unparasitized ALCM larvae (C) in the second dissection, respectively. Columns with the same letters are not significantly different ($P > 0.05$).....	21
Figure 2. 3	The mean (\pm S.E.) total mortality of ALCM larvae (A), parasitized ALCM larvae (B), and unparasitized ALCM larvae (C) in the final dissection, respectively. Columns with the same letters are not significantly different ($P > 0.05$).....	23
Figure 2. 4	The mean (\pm S.E.) total mortality of ALCM larvae (A), total parasitized ALCM larvae (B) and total unparasitized ALCM larvae (C) in the whole experiment, respectively. Columns with the same letters are not significantly different ($P > 0.05$).....	25
Figure 2. 5	The emergence patterns of ALCM (A) and <i>P. demades</i> (B)	27
Figure 2. 6	The mean (\pm S.E.) developmental duration of ALCM (A) and <i>P. demades</i> (B) from being buried in the sand after treatments to emergence. Columns with the same letters are not significantly different ($P > 0.05$).....	28
Figure 3. 1	The total mortality of fruit attached ALCM larvae (A), parasitized ALCM larvae (B) and unparasitized ALCM larvae (C) in the whole experiment, respectively.	37
Figure 3. 2	The proportion of dead ALCM cocooned larvae amount those ALCM detected in dissection.	38
Figure 4. 1	The average egg number of ALCM in UV-C treated group and control group. Columns with the same letters are not significantly different ($P > 0.05$).....	46
Figure 4. 2	The egg load of ALCM in relation to body length (mm)	46
Figure 4. 3	The egg load of ALCM in relation to body width (mm).....	47