

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.

SOME ASPECTS OF THE HOST PLANT RELATIONSHIPS OF  
POTATO TUBER MOTH, PHTHORIMAEA OPERCULELLA ZELL.  
(LEPIDOPTERA: GELECHIIDAE)

A thesis presented in partial fulfilment  
of the requirements for the degree of

Doctor of Philosophy  
in Zoology

at Massey University

PETER GEOFFREY FENEMORE

ABSTRACT

Aspects of the behaviour and biology of potato tuber moth (*Phthorimaea operculella* Zell.) relevant to host-plant selection and utilization were investigated. Literature of relevance concerning this and other insects is reviewed.

Oviposition behaviour

To provide a basis for later experimental work the fecundity and oviposition behaviour of individual potato tuber moths was investigated. Fecundity ranged from 0 to 236 eggs deposited per female for moths provided with sugar solution and muslin over filter paper as an oviposition substrate. Fecundity under these conditions was not correlated with pupal weight but the number of mature eggs in the ovaries on emergence from the pupa was related to pupal weight. This initial egg complement accounted for slightly more than half the total number of eggs laid, so that further egg maturation must take place during adult life. Females kept with males throughout their lifespan did not lay more eggs than those separated from males after an initial mating, but unmated females laid very few eggs all of which were infertile. Peak oviposition (of mated females) occurred 2 to 5 days after adult emergence.

Mated moths were offered a range of materials in a series of experiments in order to define physically optimum substrates for oviposition. Surface depressions just large enough to accommodate eggs (0.2 - 0.5 mm<sup>2</sup>) were preferred, but in addition hairy substrates were much more attractive than smooth. Mechanical stimulation of tactile hairs on the ovipositor, which was examined by scanning electron microscopy, may account for these effects. Moist substrates were highly deterrent for egg laying and also reduced the total number of eggs laid during the experimental period.

Four host plants (potato, egg plant, tobacco and tomato) and five non-host plants (silver beet, bean, pea, radish and ryegrass) were evaluated with respect to oviposition behaviour in a series of experiments. It was concluded that acceptable plants contain oviposition stimulant factors whilst unacceptable plants contain deterrent factors. Neither of these are however volatile and act for the most part only on contact. Active extracts were prepared from most plants but no attempt was made to identify individual active constituents. As these factors were released in experimental situations for the most part only when plant tissue was ruptured, it is uncertain how they are detected by the insect in the intact leaf. Strongly stimulative plants such as potato, egg plant and tobacco, induced greater total egg deposition as well as influencing the location of eggs.

#### Factors affecting fecundity

Anaesthetization with carbon dioxide as practised to facilitate handling of moths, had no effect on fecundity. Starved moths laid only slightly more eggs than the complement of fully developed eggs in the ovaries at eclosion from the pupa. Moths provided with water laid almost twice as many eggs but provision of 5% sucrose solution did not increase fecundity further.

Moths kept in the presence of potato tubers laid up to twice as many eggs over their life span compared to moths not so exposed. Isolated pieces of potato peel did not produce this effect. The factor(s) responsible for this stimulation of fecundity appears to be one of odour as tubers covered with muslin produced a similar effect compared to those to which moths had access to the surface.

#### Larval behaviour

Newly hatched first instar larvae move vigorously and continually in the absence of plant material and would be able to travel several metres before requiring to locate a suitable host plant if eggs were laid away from the plant. Mean life span of starved first instar larvae was 3-4 days at 20°C and was not greatly influenced by relative humidity at this temperature.

First instar larvae tend to be positively phototactic but do not respond to moisture. Their ability to locate host plant material is poor and no strongly directional response was detected. Movement is arrested after contact is made with leaf tissue of host plants but not to any extent with non-host plants. Newly hatched first instar larvae begin to feed soon after coming into contact with leaves of host plants but will not feed to any extent on non-host plant tissue. Discriminatory ability is thus inherited.

#### Relative susceptibility of potato cultivars

Twelve named potato cultivars were compared for degree of tuber infestation in two small plot trials, one under glass and the other outdoors. Tuber moths were artificially seeded into the experimental areas in each case. Significant differences in degree of infestation were obtained between cultivars in the outdoor trial but not in that under glass.

In laboratory tests, differences in oviposition preference were detected between tubers of different cultivars but less so with foliage. Differences were also found between cultivars in the numbers of pupae recovered following the seeding of known numbers of first instar larvae onto tubers. Pricking the surface of tubers resulted in better percentage recovery of pupae for all cultivars. No close correlation was found between percentage pupation and resistance of tuber skin to rupture or with the number of eyes per tuber. Significant differences in fecundity were recorded according to the cultivar on which the larvae were fed.

When cultivars were ranked according to oviposition preference (bare tubers), percentage pupation and fecundity, there was a close correlation with ranking based on degree of infestation in the field, suggesting that such factors are largely responsible for the differences in levels of infestation found between cultivars under field conditions.

---

ACKNOWLEDGEMENTS

I wish to thank the following persons for their assistance:  
Dr O.R.W. Sutherland for much useful discussion.  
Dr A.S. Bedi for providing tubers of named potato cultivars and coded breeding lines. Staff of Agronomy Department, Massey University for use of land and assistance with the field trial. Mr D.H. Hopcroft for taking the scanning electron microscope photographs. Miss K.V. Phillips and Mrs L.J. Mather for technical assistance, and Mrs R.O. McGee for typing the manuscript.

TABLE OF CONTENTS

	<u>Page</u>
CHAPTER I: INTRODUCTION	1
CHAPTER II: REVIEW OF THE LITERATURE	4
1. Adult behaviour and oviposition	5
(a) Plant location by the adult	5
(b) Mating	6
(c) Regulation of oviposition	7
(d) Modification of oviposition preference	10
(e) Ovipositional "errors"	11
(f) Effects on fecundity	11
2. Plant location, recognition and feeding behaviour	12
(a) Attraction and arrestment	13
(b) Feeding stimulation and deterrence	15
(c) Modification of feeding preference	16
(d) Physical factors	17
3. Plant suitability	18
(a) Toxic effects	18
(b) Nutritional adequacy	18
CHAPTER III: REARING	20
CHAPTER IV: STUDIES ON OVIPOSITION	23
1. Preliminary experiments	23
2. The physical nature of the oviposition substrate	31
3. The influence of plant tissue on oviposition behaviour	48
4. Extraction of oviposition stimulants and deterrents	60

continued/...

	<u>Page</u>
CHAPTER V: FACTORS AFFECTING FECUNDITY	66
1. Effect of anaesthetization with carbon dioxide	67
2. Influence of adult food, pupal weight and host plant tissue on fecundity	68
CHAPTER VI: STUDIES ON LARVAL BEHAVIOUR WITH RESPECT TO PLANT TISSUE	81
1. Preliminary experiments	81
2. Behaviour of 1st instar larvae in the presence of plant material	84
3. Feeding acceptance of plant species	91
CHAPTER VII: THE RELATIVE SUSCEPTIBILITY OF POTATO CULTIVARS TO POTATO TUBER MOTH	104
CHAPTER VIII: GENERAL DISCUSSION AND CONCLUSIONS	128
REFERENCES	133
APPENDIX: Publications resulting from work undertaken towards this thesis	153

---



LIST OF TABLES

	<u>Page</u>
<u>Table 1</u> Theoretical analysis of possible effects of plants on insect behaviour, development and reproduction	2
<u>Table 2</u> Relationship between mated state, number of eggs laid and lifespan for groups of potato tuber moths	29
<u>Table 3</u> Comparison of smooth fibred mesh (terylene) with hairy fibred mesh (muslin) for oviposition acceptance by potato tuber moth	44
<u>Table 4</u> Comparison of a graded series of nylon bolting cloths and muslin for oviposition acceptance by potato tuber moth	45
<u>Table 5</u> Comparison of various widths of grooves on paper card surface for oviposition acceptance by potato tuber moth	45
<u>Table 6</u> Effect of eggs present on further oviposition by potato tuber moth (filter paper surface)	46
<u>Table 7</u> Effect of position of sample discs within experimental containers on oviposition by potato tuber moth	46
<u>Table 8</u> Effect of a moist substrate on oviposition by potato tuber moth	47
<u>Table 9</u> Plant species used in experiments on influence of plant tissue on oviposition behaviour and host plant status for potato tuber moth	51
<u>Table 10</u> Effect of plant tissue, with and without muslin covering, on oviposition by potato tuber moth	56
<u>Table 11</u> Effect of plant juices, freshly expressed and air dried, on oviposition by potato tuber moth	57
<u>Table 12</u> Effect of brushing leaf surface, and of separating moths from expressed plant juices on oviposition by potato tuber moth	58
<u>Table 13</u> Effect of antennal removal on response of potato tuber moths to oviposition stimulant (potato leaf) and oviposition deterrent (bean leaf) factors	59
<u>Table 14</u> Results of extraction of plant material with solvents on oviposition stimulation and deterrence	64

continued/...

	<u>Page</u>
<u>Table 15</u> Summary of effects of expressed plant juices on oviposition compared with effects of solvent extracts	65
<u>Table 16</u> Influence of adult food and potato peel on fecundity and lifespan and relationship of fecundity to pupal weight	78
<u>Table 17</u> Influence of whole potato tubers on fecundity. Results of Experiment (2)	79
<u>Table 18</u> Influence of whole potato tubers on fecundity. Results of Experiment (3)	80
<u>Table 19</u> Response of 1st instar larvae to light	94
<u>Table 20</u> Response of 1st instar larvae to moisture	94
<u>Table 21</u> Response of 1st instar larvae to portions of plant tissue - samples inside dish	95 & 96
<u>Table 22</u> Response of 1st instar larvae to solvent extracts of plant tissue applied to filterpaper - samples inside dish	97 & 98
<u>Table 23</u> Response of 1st instar larvae to portions of plant tissue and to solvent extracts (methanol) applied to filter paper - samples <u>outside</u> dish	99 & 100
<u>Table 24</u> Results of tests to determine direction of initial movement of larvae with respect to plant tissue - samples inside dish	101
<u>Table 25</u> Results of olfactometer tests with first instar larvae	102
<u>Table 26</u> Acceptance for feeding of various plant species by newly hatched first instar larvae	103
<u>Table 27</u> Results of field trial to compare potato cultivars for degree of infestation by potato tuber moth, 1977/78	118
<u>Table 28</u> Results of oviposition preference tests with tubers and foliage of named potato cultivars	119
<u>Table 29</u> Percentage pupation following introduction of first instar larvae onto intact and pricked tubers of named potato cultivars (Experiment 1 (1978))	120
<u>Table 30</u> Percentage pupation following introduction of first instar larvae onto intact and pricked tubers of named potato cultivars (Experiment 2 (1979))	121

continued/ ...

	<u>Page</u>
<u>Table 31</u> Mean weights of pupae of mixed sexes according to the potato cultivar on which the larvae fed (Experiment 1)	122
<u>Table 32</u> Mean weights of female pupae according to the potato cultivar on which the larvae fed (Experiment 2)	123
<u>Table 33</u> Fecundity of potato tuber moth according to the cultivar on which the larvae fed (Experiment 1)	124
<u>Table 34</u> The results of skin puncture tests with tubers of named potato cultivars	125
<u>Table 35</u> The number of eyes per tuber according to cultivar	126
<u>Table 36</u> Ranking of potato cultivars on the basis of various laboratory evaluations and relationship to field infestation	127
<u>Table 37</u> Effects of plant material on behaviour of adults and first instar larvae of potato tuber moth	131

---

LIST OF FIGURES

	<u>Page</u>
<u>Fig.1.</u> Designs of containers for experiments on fecundity in relation to mated state, age and pupal weight: (a) for moth emergence and separation from pupae; (b) for collection of eggs from moths held singly or in groups	24
<u>Fig.2.</u> Patterns of egg laying for groups of 5 female potato tuber moths: (a) single-mated; (b) multiple-mated; (c) unmated	30
<u>Fig.3.</u> Distribution of eggs with different materials backing a 0.5 mm <sup>2</sup> terylene mesh	36
<u>Fig.4.</u> Distribution of eggs with a graded series of nylon bolting cloths and muslin: (a) with paper backing; (b) without backing	38
<u>Fig.5.</u> Distribution of eggs on a card surface with grooves of various widths	39
<u>Fig.6.</u> Patterns of egg laying for Experiment (1): (a) No potato peel. Moths starved (b) No potato peel. Moths fed distilled water (c) No potato peel. Moths fed 5% sucrose solution (d) Potato peel. Moths starved (e) Potato peel. Moths fed distilled water (f) Potato peel. Moths fed 5% sucrose solution	72 & 73
<u>Fig.7.</u> Patterns of egg laying for Experiment (2): (a) No access to potato tuber. No odour (b) No access to potato tuber. Odour (c) Access to potato tuber. Odour	74
<u>Fig.8.</u> Patterns of egg laying for Experiment (3): (a) No access to potato tuber. No odour (b) No access to potato tuber. Odour (c) Access to potato tuber. Odour (d) Access to potato tuber. Odour. Plus additional oviposition sites	76
<u>Fig.9.</u> Mortality of starved 1st instar larvae at various temperatures and humidities	85
<u>Fig.10.</u> Design of olfactometer for tests with 1st instar larvae	88

LIST OF PLATES

	<u>Page</u>
<u>Plate 1.</u> External structure of the ovipositor of potato tuber moth: (a) entire ovipositor, ventral view (x 80); (b) entire ovipositor, lateral view (x 95); (c,d) part of tip of ovipositor in close up, showing two types of hairs (x 570 and x 950 respectively)	42 & 43

---