# THE DEVELOPMENT OF INSECTICIDAL BAITS FOR THE CONTROL OF PORINA (<u>Wiseana</u> Spp.)

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Porina (*Wiseana* spp) damage in the field (left) and a porina caterpillar in it s subterrranean burrow (right).

# ABSTRACT

Investigations in the development of chipped wheat baits for porina control were carried out in the laboratory and the field. In the laboratory porina readily accepted untreated chipped wheat in the presence of white clover (Trifolium repens L.) or perennial ryegrass (Lolium perenne L.). They also accepted equally, three different sizes of wheat baits, and fed at temperatures between -2°C and 25°C. Porina accepted insecticidally treated baits in the presence of untreated wheat or white clover, however did not readily accept fungus (Metarrhizium anisopliae (Metsch.) Sorok.), infected wheat in the presence of the latter two foods. Baits were removed by porina from around their burrow mouths when applied to the surface of turfs held under controlled conditions. The number of baits removed per active porina was related to the density applied.

Field trials demonstrated that insecticidally treated baits, of the smallest size (528 chips/g. dry weight), being the most cost-efficient, gave comparable mortalities to conventional spray applications. After 10 days fenitrothion spray (0.9 Kg ai/ha) gave 95% control of porina populations, and with fenitrothion treated baits (0.13 Kg ai/ha) applied at 1 chip/6.25 $cm^2$ the control achieved was 83%. At a lower bait density (1 chip/25 $cm^2$) a significant increase in mortality was seen between 10 and 30 days. The addition of a molluscicide onto a treated bait increased its efficiency by 10%. Applying baits infected with the fungus Metarrhizium resulted in 53% mortality of porina.

The optimal bait density was shown to be one wheat chip/12.5 $cm^2$, and the optimal dosage of fenitrothion 0.4% ai/g. dry weight of wheat. The cost of bait treatment, including application costs, for porina control was $15/ha, compared to $46/ha for spraying.

## ACKNOWLEDGEMENTS

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# CHAPTER ONE

## INTRODUCTION

### 1.1 THE PEST

1.1.1. Porina (Wiseana spp.) is a serious pest of developed pastures throughout New Zealand, south of a line from New Plymouth to Napier. The adult moth does not feed, but the caterpillar is a nocturnal foliage feeder spending most of its larval stage in a vertical subterranean burrow. Loss of pasture production can be considerable, along with the degeneration of the pasture composition. The present study was designed to evaluate the use of baits as a cheap and efficient method of managing the pest.

1.1.2. Classification of Wiseana spp. is not definitive (Dumbleton 1966). Originally the species were designated the genus Porina (Cockayne 1915 Gourlay 1931) but later were incorporated under Oxycanus (e.g. Kelsey et.al. 1950). The present terminology lists porina under their own genus Wiseana (e.g. Gaskin 1964), and splits into at least three clearly defined species; Wiseana cervinata, W. umbraculata and W. signata. The presence of other species is not clear (Perrott 1974), but a number are classified in the complex (Dugdale 1969, Dumbleton 1966). W. cervinata and W. umbraculata dominate the pest complex with the former being most common. Relative proportions, species abundances and flight periods in different localities have been elucidated from light trappings (Carpenter & Wyeth 1980, Cumber 1951, Dumbleton 1945, 1966, French 1979, Gaskin 1964, Helson 1967) and these can be used to predict pasture damage by porina caterpillars.

1.1.3. Identification of porina moths between the three main species can be done visually through inspection of general wing colouration and markings (Gaskin 1964, T.K. Wyeth pers. comm.). Porina, being Hepialids, show traits of this family e.g. wings folded over body in tent-shape when resting. Visually porina are light brown moths, with white patterned forwings, non-patterned hindwings often with a reddish tinge, and vary in wingspan between about four to ten centimetres with the females being the larger.

At present specific identification of Wiseana larval stages is not possible. The caterpillars pass through between fourteen to twenty instars, which may be dependent on species and/ or locality (A. Carpenter pers. comm.). Field populations in the study areas comprised a range of instars and species, which could not be identified by size. For this reason and the similarity in morphology between species, larval feeding behaviour in these studies has been taken to be identical.

1.1.4. The life cycle is typically univoltine. The adult female mates soon after leaving the puparium generally in September to March, depending on species and locality (Helson 1967). She lays up to 3,000 eggs either while flying (French 1979) or directly on pasture plants (Cottier 1962, Pottinger 1977). The ½ mm diameter eggs are white when laid, but change to black within a few hours. Hatching time is variable between 3-5 weeks (Dumbleton 1945, Fenemore and Allen 1969, French and Pearson 1979) and the small larvae spend about 6 weeks above ground sheltering in foliage loose soil webbed together with silk. (A. Carpenter pers. comm.). When about ten to twenty centimetres long the larvae begin to excavate a vertical burrow in the soil, which lined with silk may reach 25-30 cm in depth at maturity of the caterpillar. From the mouth of the vertical burrow a horizontal burrow is extended, constructed of loose debri and foliage webbed together. The porina protrudes from this to feed, but seldom totally leaves its shelter (M.J. Esson pers. comm.) Under profuse foliage cover or in heavily trodden or wet conditions, this burrow may be absent or limited to a protective mound over the exit hole. In short pasture the horizontal tunnel serves as an extention to the larvae's feeding range, since this tunnel may be extended, or abandoned for another in a different direction.

The larvae after approximately seven to eight months of feeding through the autumn, winter, and early spring, enter a short prepupation period. At this stage the larvae may be up to 8 cm in length, and over 2 gms in weight. The reddish-brown pupae is still mobile in the burrow and the adult emerges at the surface at dusk or later, on generally overcast nights after approximately six weeks.

## 1.2. PORINA DAMAGE

The effect of porina is most evident when infested pasture is at stress periods, during such time that average pasture consumption by stock and porina caterpillars exceeds pasture regrowth. The frequency of these periods is influenced by two major factors. Firstly, the dynamics of porina populations which are controlled by interacting factors such as weather, both seasonal and local (Fenemore and Allen 1969, French 1973(a), French & Pearson 1978), natural controlling agents (Crawford and Kalmakoff 1977, Eyles 1965, 1966, Kalmakoff and Crawford 1976, Latch 1965, Moore 1973), pasture management (French 1973(a), (b), 1975, Farrell 1976) and soil structure (French 1973(a)). Secondly the type and intensity of farming practiced influences such things as, the importance of the feed at certain periods of the year, the flexibility of the farming system and the efficacy of using insecticidal and cultural control procedures (French 1973(a), 1975) and fertilizers (Harris 1973).

Additional to these two factors is the long term effect that a large porina infestation has on pasture composition. The replacement of dominant pasture species by weeds is common (Cassels 1966, Christie 1965, Fenemore and Allen 1969, French 1973a, McLaren and Crump 1969, Patterson 1966, Taylor 1966). This has the effect of lowering the overall herbage production and therefore accelerating the onset of a stress period.

### 1.2.1 Porina in the Lower North Island

Porina is a severe pest of much of the southern North Island region of New Zealand (Kain *et. al.* 1979). All types of pastoral farming in the region ranging from the intensively farmed flat to rolling country devoted to fat stock and dairy production, to the store sheep and cattle farms of the steep hill country are affected. Cyclic outbreaks (French 1973) occur in many areas, whereas in others the problem is severe from year to year. There are indications that the pest is becoming more prevalent (R. Darwin *pers. comm.*)

The sensivity of farming to porina infestations within the region varies considerably. In intensively farmed dairy country the feasibility of applying insecticides or more fertilizer, is high. On lowland sheep and cattle farms where outbreaks occur sporadically the latter method is generally adopted. On the less intensively stocked hill country areas, the porina populations largely go unchecked, although farmer awareness of the pest is evident (Wilson 1974). It is here that the use of traditional insecticide applications are considered uneconomic because of the high cost of chemicals, their transience, difficulties of obtaining suitable conditions for spraying (as much of the region is buffeted by high winds and rain, from autumn to early spring), the steep contour of much of the hill country, which presents application problems (Kain et. al. 1979) and the overlapping generations of at least two species of porina (Carpenter and Wyeth 1980). An avenue which offers a number of advantages is the use of baits for porina control.

## 1.3 THE USE OF BAITS FOR INSECT CONTROL

The use of chemically treated or toxic baits against pest animals, particularly vertebrates,is common, but the use of these in insect control has been limited (Peregrine 1973). The use of baits against insects is increasing (Table 1), due to mainly their characteristics of selectivity, low insecticidal loading, persistence, more precise application under difficult conditions and versatility.

TABLE 1 Examples of types of insects controlled by baits.

| Insect Type (Common name) | Country | References |
|---|---|---|
| Ants | Trinidad | Cherrett (1969) |
| | " | Cherrett & Merrett (1969) |
| | " | Cherrett and Sims (1969) |
| | Cent. & Sth. America | Phillips and Lewis (1973) |
| | | Lewis (1972, 1973) |
| | | Lofgren et.al. (1975) |
| Armyworm | USA | Sechriest and Moore (1972) |
| Crickets | NZ | Blank et.al. (1980) |
| | USA | Folson and Woke (1938) |
| | USA | Foster et.al. (1979) |
| | NZ | Smith (1966) |
| Cutworm | NZ | Martin (1980) |
| | USA | Sechriest (1968) |
| Grasshoppers | South Africa | Coaton (1939) |
| | USA | Cowan (1934) |
| | USA | Guice (1940) |
| | USA | Mitchener (1941) |

### 1.3.1. The history of baits for porina control in New Zealand

In the past, bran (Anon 1943 . Dumbleton 1944, Dumbleton and Dick 1941, 194 , Dumbleton et.al. 1948) baits treated with inorganic insecticides and kibbled (crushed) wheat treated with organochlorides (Kelsey 1965) were used for porina control. Because the former insecticides were slow acting the pest consumed large amounts before death and therefore these formulations were less effective at high than low pest densities but generally gave acceptable levels of control. The later were less cost effective since the use of DDT and BHC in superphosphate would,control porina more cheaply than applying baits alone, controlled other insect pests, especially grass grub *Costelytra zealandica* and a residual effect was noted (Doull 1951 a,b, Kelsey et al 1949,1950). Baits were therefore superseded in 1951 with the advent of these synthetic insecticides. In 1967 DDT was banned for use on pastures and this led to the evaluation of replacement chemicals especially organophosphates (Kelsey and Reid 1966, Lowe 1966, McLean 1968, Taylor 1966) and to the endorsement of fenitrothion, generally applied as a spray, for porina control (Waller 1968).

## 1.4 THE PRESENT STUDY:

The initial studies on the re-evaluation of wheat baits for porina control have been reported by Kain et. al. (1979). The solid nature of wheat makes it ideal for persistence in the field (Blank 1980) and easy spreading qualities (Martin 1980), Kain et. al. reports that wheat baits coated with a vegetable oil were acceptable, and Martin (1980) states that this is a satisfactory diluent and sticker for insecticides on bait. This study evaluates the use of chipped wheat baits for porina control in the future.

The general trend in the 1970's in porina research has been away from just testing new insecticides, and towards a better understanding of the pest in relation to controlling it (e.g. French 1973, Moore 1973). Therefore these studies were based upon questions asked about basic bait acceptance in the laboratory and how these related to the field situation, and then applying insecticidally treated baits in the field to assess the effects. Wherever possible questions posed at the beginning of this study (Table 2) were answered in turn and the studies carried on in a step-wise sequence, with these as guides. In this way, field trials to develop baiting could be planned and assessed with knowledge of the feeding behaviour of porina in relation to bait acceptance, allowing such things as optimal bait size to be gained before these trials commenced.

TABLE 2: Questions posed at the beginning of these studies.

| Laboratory | Field |
|---|---|
| (a) Do porina accept chipped wheat baits: | (a) Do porina accept treated baits: |
| . by themselves? | . in the field situation? |
| . at different temperatures? | |
| . of different sizes? | (b) what relationships exist between treatments and: |
| . with foliage present? | |
| . in a natural situation? | . percentage kill? |
| | . bait acceptance? |
| (b) Do porina show selection preferences: | . persistence? |
| | (c) Are different insecticides, molluscicides, or a fungus equally successful in controlling porina? |
| . between bait and foliage? | |
| . between sizes of baits? | |
| . between treated and untreated baits? | |
| (c) What relationships in acceptance exist in a natural situation between: | (d) What relationships exist between mortality and: |
| . different bait rates? | . density of bait? |
| . different temperatures? | . dosage on bait? |
| . different sizes? | . treatment of bait? |

# CHAPTER TWO

## GENERAL METHODS

## 2.1 BAIT SIZES, TREATMENTS AND ANALYSIS

### 2.1.1 Bait sizes

Chipped wheat baits of three sizes, obtained from Hodder and Tolley Ltd., Palmerston North, were used for these studies. These were 528 chips/gram, 152 chips/gram and 92 chips/gram, termed wheat size No. 1, No. 2, and No. 3, respectively.

### 2.1.2 Treatments

To aid identification of baits on the ground surface an inert red dye 'Rhodamine B', was used in parts of Chapters 6, 7, and 9. This was applied by dissolving a few grains of the dye in water, mixing this with the wheat, and then drying it with continual mixing.

Where chipped wheat baits were given insecticide treatments, (Table 3) unless otherwise stated the concentration was constant at 0.4% active ingredient per gram dry weight of wheat (% ai./g.dwt.). In field trials a concentration of 0.5% vegetable oil/g.dwt. was used. The formulation method for treated baits was to place the chipped wheat, insecticide and oil into a plastic bag and thoroughly mixed by shaking and kneading. These were then left overnight, and applied in trials thereafter.

*Metarrhizium anisopliae* treated baits cultured on wheat size No. 2, were obtained from G.C.M. Latch, D.S.I.R., Palmerston North. These were stored in suitable containers at 7°C until used in the laboratory and field studies, and were regularly checked for alien fungal contamination. Application of insecticide to these for specific trials, was by the same method as above, except that no oil was used in the formulation.

TABLE 3 Common names and full names of chemicals used in these studies (from Thom son 1973)

| | |
|---|---|
| Actellic (or perimophos-methyl) | - 2 - Diethylamino - 6 - methylpyrimidin - 4 - yl dimethyl phosphorothionate. |
| Fenitrothion | - 0,0 - Dimethyl 0 (3-methyl-4-nitrophenyl) phosphorothiosate. |
| Lindane | - gamma - 1,2,3,4,5,6 - Hexachorocyclohexane |
| Metaldehyde | - metacetaldehyde |
| Methiocarb | - 3, 5 - Dimethyl-4- (methylthio) phenol methylcarbamate. |
| Vydate (or oxamyl) | - Methyl $N^1$, $N^1$ - dimethyl-N- (methylcarbamoyl) oxy) - 1 - thiooxamimidate. |

2.1.3 Analysis

All analysis of variance calculations were carried out either on a Hewlett-Packard HP 1810, or a Prime 750 computer.

## 2.2 LABORATORY METHODS

### 2.2.1. Porina collection and storage

Porina caterpillars were collected in the field for laboratory feeding studies by digging and sorting soil samples in infested areas. Healthy larvae were placed individually in clean, 9 cm petri dishes lined with moist filter paper, with a portion of exercised foliage. These dishes were taped together in stacks, placed in plastic bags and transported back to the laboratory. A chilly-bin was used if necessary, to protect porina from overheating and desiccation. These larvae were stored at 7°C in a cooler, and fed, cleaned and watered every third day until used in feeding studies. This method of collection, transport and storage of porina in petri dishes was also used for post-sampling observations of porina from field trials, except that these were kept at 15°C.

Various modifications to this standard method were used under appropriate circumstances. Field soil was used instead of filter paper, for larvae to be used in lunch-box studies, if the incidence of the fungus, Metarrhizium anisopliae did not cause significant mortality. Also various different types of containers were used, with the major necessary feature of these being that they were airtight, since a high humidity is a very important factor in larval survival (Elder 1970).

2.2.2. Petri dish feeding studies

Lots of ten individual porina were used in these studies. Clean, 9 cm, plastic petri dishes were prepared by placing two layers of Whatman No.1 filter paper in the bottom, moistening these with a measured amount of water and placing weighed amounts of food material, and an individual porina inside. They were then each sealed with insulation tape, and placed under experimental conditions.

All weights were recorded on a 'Mettler' eletric set of scales, with digital readout to 4 decimal places.

2.2.3. Lunch-Box selection studies

These were carried out in clear plastic airtight containers measuring 18 cm long, 12 cm wide and 8 cm deep. The boxes were prepared by shaping and placing a 2 cm thick sheet of polystyrene, with two overlying pieces of moist filter paper, in the bottom. A cardboard partition was inserted to split the box into two, and in each side, abutting with this wall, an artificial 'hide';consisting of a 11 cm x 2.5 cm x 2.5 cm hollow polystyrene block, was pinned. Arranged in a semi-circle equidistant from a central exit hole cut in the block, were six evenly spaced, 2.5 cm pins each supporting, three quarters up their length, a 1 cm x 0.3 cm x 0.3 cm block of pith. In this inert material was placed a micro-pin, allowing a portion of food to be skewered onto it and held 1 cm above the floor of the container and about 3/4 cm horizontally out from the supporting pin.

On the commencement of each trial, a small portion of each food source was placed on alternative pins, and a healthy porina placed inside the 'hide'. Two foods were used in each trial to compare their removal, and therefore acceptability, after 2 days. Where wheat was being tested, a single grain was used to skewer onto a micro-pin, and in the case of foliage a small white clover (Trifolium repens) leaf (approx. 0.4 cm in radius) or a cut blade of perennial ryegrass (*Lolium perenne*) (about 0.8 cm long) was used.

### 2.2.3 Acceptance of baits under controlled natural conditions

These studies were carried out on infested turfs held in steel bins measuring 1.0 m (long) x 0.7 m (wide) x 0.3 m (deep). These were filled with turf by means of a tractor mounted implement, which allowed the bin to be pulled firstly into the ground, and then under the ground parallel to the surface at a depth and distance which filled it to its capacity. The turf was then cut flush with each end, and a front-end loader was used to lift the bin and contents onto the back of a truck and transported back to the laboratory. In the growth rooms, tin end-plates were constructed and put on the ends of each bin to stop spillage.

The laying of baits on the surface in these studies, and in the future Hauorongo field studies, was accomplished with the use of specially designed grids. These were 0.5 m x 0.5 m, and constructed of a 1 cm square steel pipe frame, with interlaced synthetic electric fence cable making up the internal grid pattern of varying sizes. Baits were placed individually with forceps onto the surface of the ground, through these overlying grids, to give the different baiting application rates. The disappearance of baits from the surface was measured by replacing the grid and counting the number of squares which still retained a chip of wheat.

## 2.3 FIELD STUDIES

Field sites were located by visual assessments of populations in known porina infested pastures. These visual assessments relied on the identification of obvious burrow surface characteristics and pasture damage, and were proven by soil sampling.

Treatment plots were sampled by digging with a spade. The samples were generally split into four sections, dug to a depth of about 15 cm removed and sorted. A further 15 cm, or to the depth of the underlying clay layer, whichever came first, of soil was carefully dug, removed and sorted. Porina numbers of alive and dead were recorded, with caterpillars that showed clear insecticidal poisoning classed as dead. The incidence of *Metarrhizium* infected dead larvae was recorded, knowing that there are three distinguishable phases in fungal development;

1. Early infected; hard, distended, yellow cadavers.
2. Mid infected; hard, distended, white fungal development on cadavers.
3. Late infected; hard, distended, deep green sporating fungal development on cadavers.

All samples were checked for missed individuals as the soil was replaced.

2.3.1 Cover readings

Point analysis of pasture was carried out using a 5 pinned point analyser, 0.6 m long with evenly spaced pins, 0.1 m apart. From small plot field trials 20 point readings per plot were taken, and in the large plot trials, 100 readings per site were taken. In both cases pasture species, either one or more, that were hit by each pin point on its travel to the ground were recorded. These points were located over the plot or site evenly, to allow mean percentage cover or bare ground to be calculated. Some pasture species were split into groups for convenience of recording.

# CHAPTER THREE

## STUDY AREAS

### 3.1 LABORATORY STUDIES

All laboratory feeding studies with porina were carried out in the facilities of, the Pastoral Research Group, Ministry of Agriculture and Fisheries, and the Botany & Zoology Department, Massey University, Palmerston North.

### 3.2 FIELD STUDIES

Both field sites were located in the porina infested rolling and steep hill country of the Lower North Island. A relatively harsh climate is typical of both the localities in this extensively grazed sheep country. The two areas contrast each other in that the first was lower in porina populations, has an earlier peak flight period, is more fertile and is less steep than the second site.

#### 3.2.1 Hauorongo study area

Small plot field trials (Chapter 10) were conducted from late July till September at Hauorongo, formerly the 'Best Estate', situated approximately 8 kilometres (Km) by road east of Massey University (Figure 1). This area is owned by the Ministry of Agriculture and Fisheries (MAF), Palmerston North and is used for pastoral research. It is sited on rolling country consisting of developed pastureland. The locality is exposed, and therefore prone to bitterly cold winds and rain throughout the winter. The soil consists of Shannon silt loam (rolling phase) probably merging with Tokomaru silt loam, and has a dark brown topsoil which is well drained, reasonably structured and fertile (J.A. Pollok *pers. comm.*) A compact yellow clay layer at about 30 cm depth is typical. Average yearly rainfall is approximately 1000 mm (N.Z. Met. Service 1979).

The area has a history of sporadically occurring, moderate to high infestations of porina caterpillar. The main species present is *Wiseana cervinata*, with *W. umbraculata* less prevalent.

The flight period spans September till March, with generally a single flight peak occurring between early November and mid December (Carpenter & Wyeth 1980). Visible pasture damage occurs from April onwards.

### 3.2.2 Waikanae study area

Large plot field trials were conducted from early October till late December, on the sheep grazing property ('Ratadale') belonging to G. M. Thompson which is situated approximately 10 km by road south east of Waikanae (Figure 1). The farm mainly consists of improved pastures, and also has areas of partially broken in and unbroken steep hill country covered with natural vegetation. Altitude does not exceed 350 metres above sea level. The soil type is Kiwitea silt loam, well drained, friable and of moderate fertility, merging into the infertile skeletal soils of the steep country. (J.A. Pollok *pers. comm.*) Average yearly rainfall is approximately 1600 mm (N.Z. Met. Service 1970, 1971, 1974, 1979).

The area has a history of very high populations of porina. The two main species are again *W. cervinata* and *W. umbraculata*, and their flight periods span October till April, with two distinct peak flights per year. The first smaller peak generally occurs in November, and the second from mid-February to late March (Carpenter & Wyeth 1980). Visible pasture damage is evident from July, and earlier if high infestations result from the small November flight.

## 3.3 TARANAKI FIELD COLLECTION SITE

In February 1980, a field collection of porina for laboratory studies was made, at the Taranaki Agricultural Research Station (T.A.R.S.), M.A.F., Normanby, near Hawera.

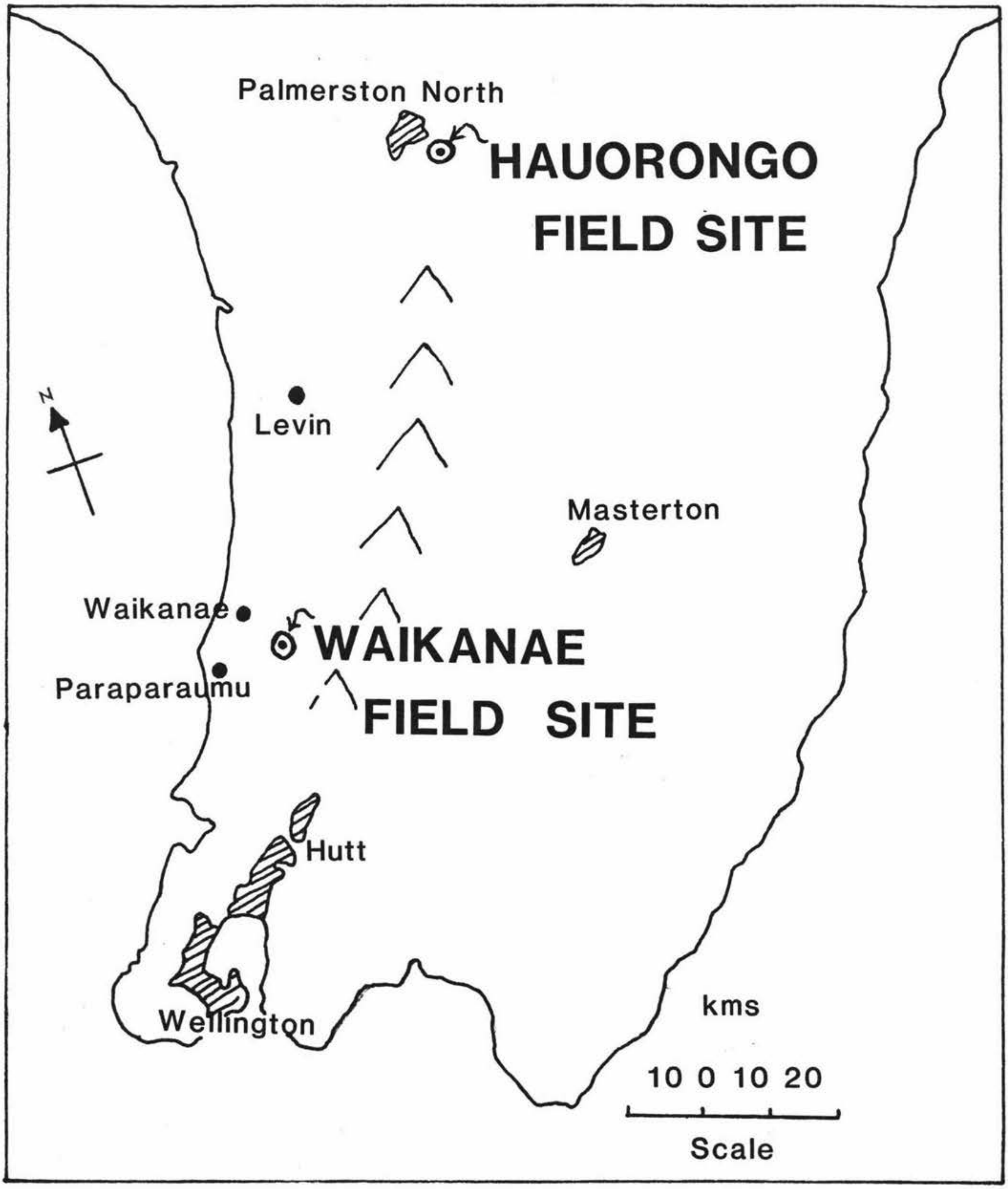


Figure 1: A map showing the locality of the two field experimental sites, Hauorongo and Waikanae, in the lower North Island.

# CHAPTER FOUR

## PETRI DISH FEEDING STUDIES

### 4.1 INTRODUCTION

Porina caterpillars emerge from their burrows at night to feed on pasture foliage. Their feeding behaviour previously has been studied by:

(1) Time-lapse photography in the field (Esson 1970);

(2) Modification of the food source in the field (French 197 Kain 1979);

(3) Indirect observations and assessments of the ecology (e.g. French 1973), the effects on the pasture system (Farrell 1976, Harris 1969) and the outcome of management procedures (e.g. Harris 1973);

(4) Observing the behaviour of the animal after removing it totally from, or with part of, its natural surroundings, and placing it in controlled easily manipulated experimental conditions (M.J. Esson pers. comm., Farrell et. al. 1974, W.M. Kain pers. comm.)

This study falls into the last category. Porina caterpillars were studied under completely artificial conditions in the laboratory by Farrell and co-workers (1974) and further such studies may be advantageous to our understanding of the pest life system (French & Thomas 1971, Waller 1968a). Overseas laboratory studies have been carried out with related species of hepialids (Elder 1970, Jou bert 1975). In New Zealand however, there is a dearth of published work in this area of research probably because:

(i) the time involved in handling large numbers of porina individually, especially since they injure each other if kept together;

(ii) the assumed difficulty with artificial rearing (Waller 1968b, Fenemore & Allen 1979, Wood 1970);

(iii) the justification for such studies (W.M. Kain pers comm.);

(iv) complications with experimental technique, especially those relating to measurements.

Isolated individuals have been kept in the laboratory either for storage or other purposes (Elder 1970, Dodgshun 1970, Fenemore & Allen 1979, French & Thomas 1971, Moore 1973). Artificial rearing of porina therefore presents no great technical difficulty if two major factors are stressed; a high humidity and fresh food (Elder 1970, W.M. Kain pers. comm.) A third factor, also very important, is a source of roughage in the diet since porina naturally consume amounts of soil, as do other species of hepialids (Jourbet 1975). In these studies filter paper in the experimental dishes, and filter paper or soil in the field collecting and storage dishes fulfil this role.

The need for information on bait acceptance in petri dishes is directly related to the aims of this thesis, and therefore to the practical use of insecticidally-treated chipped wheat baits. The object of these experiments was to study the acceptability of;

- different sizes of baits at one temperature.
- bait of one size with natural food (foliage) present.
- bait of one size at different temperatures.

Relationships between treatments were elucidated from differences in the amounts of food consumed. The number of faecal pellets and bait chips, and caterpillar live weights, (measured before and after each trial), were recorded to give additional data on feeding behaviour. This allowed assessments to be made as to whether porina in the field would, firstly, consume a chipped wheat bait with pasture present, secondly, select a certain size of bait, and thirdly, whether bait acceptance would be adversely affected by the ambient temperature.

The biggest disadvantage of all feeding studies is that immediately the food consumption of any organism is measured its normal feeding behaviour is altered in some way (French 1973 a). Therefore the amounts of food eaten by the larvae in artificial conditions may not necessarily be equivalent to their field consumption. However, the relationships between bait and foliage acceptance should not be significantly altered, if sources of experimental error are minimized.

In the preference and size treatments, differences in amounts eaten does not necessarily relate to "yes - no" selection preferences. As porina exhibits relatively random food selection (Kain 1979), offering food in petri dishes may show that porina will eat whatever is present. However, in the field porina prefer clover (Trifolium repens L.)and cocksfoot (Dactylis glomerata L.) over perennial ryegrass (Harris 1969), and high resistance to tall oat-grass (Arrhenatheum elatius) sweet vernal (Anthoxanthum odoratum L.), Phalaris and Lotus pedunculatus **Cav.**, has also been shown in the laboratory (Farrell et. al. 1974). Porina when fed in confined conditions with two food sources is likely to exhibit preference by eating more of one of the two foods offered. When fed with different sizes of a single food source, or at varying temperatures, the difference in consumption between treatments should reflect a real preference.

## 4.2 SPECIAL METHODS

### 4.2.1 Field Collection

Porina were collected in the field at the Taranaki Agricultural Research Station (T.A.R.S.), Hawera, in February 1980 by the method described earlier (page 9 ). These larvae were then held in the laboratory at 7°C in petri dishes.

### 4.2.2 Selection of experimental lots

One hundred and twenty caterpillars were individually weighed before commencement of the study. These were placed in descending order of **size** and sorted into lots of ten, from which caterpillars were selected at random, making up to ten in each treatment. By this method the chance that significant mean weight differences occured between treatments was minimized.

### 4.2.3 Experimental design

Twelve treatments were used, each consisting of fifteen petri dishes, ten containing an individual caterpillar and a food source(s), and five controls containing only food.

Treatments are shown in Table 4 . A single chipped wheat food source, wheat size No. 2 was tested at varying temperatures. At 15°C wheat size No.1, size No.2 and size No. 3 were compared. Paired foods, of white clover (Trifolium repens L.) and chipped wheat (No.2); perennial ryegrass (Lolium perenne L.) and chipped wheat (No.2); and white clover and perennial ryegrass were offered at 15°C. White clover and chipped wheat (No.2) was offered over a range of temperatures. Caterpillars were placed, between each period, in petri dishes which were always clean before use, as described on page 10 .

Where possible each set of ten was passed through treatments of 2 days, 4 days, and 6 days duration with a waiting period of one day at 10°C between each treatment. Replicates were taken, where possible, using a different set of caterpillars. In the bait-size versus temperature trials it was found that intermediate temperatures needed to be tested later, after the trends were elucidated, to enable the relationships to be further substantiated. These temperatures were -2°C, 0°C, 3°C, 7°C and 25°C.

TABLE 4 : Treatments originally used in petri dish feeding studies.

| Temperature (°C) | Food source(s) | | | | | |
|---|---|---|---|---|---|---|
| | Wheat Size 1 | Wheat Size 2 | Wheat Size 3 | White Clover + Wheat (Size 2) | Perennial Ryegrass + Wheat (size 2) | Perennial Ryegrass + White Clover |
| 5°C | | X | | X | | |
| 10°C | | X | | X | | |
| 15°C | X | X | X | X | X | X |
| 20°C | | X | | X | | |

4.2.4 Experimental Technique

Pilot experiments were conducted to test whether porina fed freely in petri dishes and on how much. The results enabled the experimental porina to be fed on adequate (but not excessive) amounts of food over the period of each trial. This assessment hinged upon the consumption of the largest individual, since each lot of ten test animals were fed approximately equal amounts of food. White clover and perennial ryegrass were gathered from the field before the commencement of each trial. Uniformly sized leaves of white clover were each cut centrally, with a 4 mm radius corkborer, into circles. Perennial ryegrass leaves were selected for uniformity of size, and 5 cm lengths were cut from these with scissors. Chipped wheat was taken from a bulk supply stored at 5°C.

Chipped wheat, white clover and perennial ryegrass were weighed before and after the feeding period, and the amount eaten over the period corrected from the controls on a fresh weight basis. An increase in weight was recorded for all the controls due to the high humidity within the dishes. The number of items of each food source was recorded after each trial, with the initial number being uniform within each. Faecal numbers, caterpillar weights and observations on moulting were also recorded before and after each trial. Standard errors of means, where calculated, are to 95% confidence limits.

## 4.3 RESULTS

### 4.3.1 Temperature relationships when fed chipped wheat (No. 2)

Porina fed readily on chipped wheat baits when offered in petri dishes (Table 5). The relationship between the amount eaten of No. 2 (156 wheat chips/gram dry weight) wheat and temperature is shown in Figure 2. Over 2 days (Figure 2) feeding increased with temperature, reaching a peak at approximately 20°C. Porina fed at temperatures as low as -2°C, although over both two and four day intervals the number of non-feeding individuals at this temperature was higher than normal. A proportionately higher increase of food intake was seen over the 0-10°C range than other temperatures at both time intervals. The six day trial results were erratic, probably due to food source decay, and therefore trials were not attempted with intermediate temperatures.

TABLE 5: Amount (mg ± SE) of chipped wheat bait (No.2) eaten with varying temperatures over two and four days.

| Temperature (°C) | Weight eaten (mg ±SE ) | |
|---|---|---|
| | 2 days | 4 days |
| -2 | 0.1 ± 0.2 | 1.6 ± 0.5 |
| 0 | 4.5 ± 1.4 | 4.6 ± 0.9 |
| 3 | 6.5 ± 2.0 | 14.9 ± 3.7 |
| 5 | 13.3 ± 4.0 | 20.5 ± 4.6 |
| 7 | 14.1 ± 4.3 | 26.5 ± 6.5 |
| 10 | 26.3 ± 6.2 | 36.7 ± 7.8 |
| 15 | 31.4 ± 4.6 | 46.6 ± 4.9 |
| 20 | 32.9 ± 7.4 | 53.1 ± 9.6 |
| 25 | 32.3 ± 7.1 | 59.0 ± 13.0 |

The amount of wheat consumed during each of the two and four day intervals at any given temperature did not show a consistent one:two relationship. The most probable explanation is that a burst of feeding activity occurred after the caterpillars were placed in their new environment with fresh food. Feeding rates stabilized when the caterpillars adjusted to this new environment.

10.7% of the porina in the wheat-only treatments did not feed and 28.6% of the live larvae had lost weight (Table 6 ). It is possible that if porina behave by having periods of feeding and non-feeding, weight loss may occur in some individuals between these periods. If so, since there is a delay between ingestion and digestion, it would be expected that weight changes would lag, in time, behind the feeding or non-feeding periods. The peak of feeding would be more advanced than the peak of weight increase, and therefore a period of non-feeding and weight gain would result. The opposite effect may be seen where weight loss would continue for a short while after feeding has recommenced.

TABLE 6 : Relationship between feeding, and weight change (live larvae)

| Category | % of individuals | No. of individuals |
|---|---|---|
| Didn't feed and lost weight | 6.3 | 33 |
| Didn't feed and gained weight | 3.7 | 19 |
| Did feed and lost weight | 18.1 | 94 |
| Did feed and gained weight | 71.9 | 374 |

Changing the temperature had little effect on whether or not feeding occurred, and loss of weight amongst larvae (Table 7 ). Porina fed at temperatures as low as -2°C but at this temperature a high percentage of individuals lost weight.

TABLE 7: Percentage (%) of porina feeding and those loosing weight at different temperatures (including dead larvae).

| Temperature (°C) | % Didn't feed | Total Number kept | % Lost Weight |
|---|---|---|---|
| -2 | 15 | 40 | 50 |
| 0 | 15 | 40 | 35 |
| 3 | 2.5 | 40 | 20 |
| 5 | 7.5 | 90 | 10 |
| 7 | 20 | 40 | 24 |
| 10 | 4 | 60 | 22 |
| 15 | 10 | 50 | 34 |
| 20 | 12 | 50 | 27 |
| 25 | 10 | 40 | 35 |
| Mean | 10.7 | | 28.6 |

Average mortality over all temperatures was 5.4%. When related to temperature, only those exposed to -2°C over 4 days showed a marked increase in their mortality (Table 8). At all temperatures, of those that died, 92% had fed, indicating that in containers with easily accessible food, stressed or sick individuals will feed up to a short time before death.

TABLE 8: Mortality of porina kept in petri dishes at different temperatures (fed on wheat baits).

| Temperature (°C) | Mortality (%) | Total Number kept |
|---|---|---|
| -2 | 20 | 40 |
| 0 | 0 | 40 |
| 3 | 2.5 | 40 |
| 5 | 4 | 90 |
| 7 | 4 | 40 |
| 10 | 3.3 | 60 |
| 15 | 4 | 50 |
| 20 | 10 | 50 |
| 25 | 5 | 40 |
| Mean | 5.9 | |

Moulting individuals had an 11.8 percentage-occurrence of non-feeding, which was similar to the overall 10.7%. However, 70% of these porina, lost weight, an almost three-fold increase to the average.

### 4.3.2 Acceptability of different size chipped wheat with constant temperature

The weights of different sized wheat baits eaten was assessed over 2 days, 4 days and 6 days at 15°C (Table 9). The results were not uniform between the periods and the three sizes. The highest amount eaten was over the four day period and the smallest sized bait. However over the two day interval the medium sized bait was preferred. Over six days, observations suggested that decay and germination of the wheat was a problem. The number of baits, or bait fragments left after three periods did not show a definite relationship between the size of bait and the amount eaten.

TABLE 9: Comparison of the mean number and weight ( mg±SE) of bait taken (15°C)

| Size of bait | 2 days | | 4 days | | 6 days | |
|---|---|---|---|---|---|---|
| | Numbers | weight (mg±SE) | Numbers | weight (mg±SE) | Numbers | weight (mg ±SE) |
| No.1 | 13 | 15.5 ± 5.6 | 16 | 86.0 ± 19.4 | 20 | 57.6 ± 17.2 |
| No.2 | 10 | 31.4 ±11.3 | 25 | 46.6 ± 16.5 | 13 | 40.8 ± 14.0 |
| No.3 | 4 | 28.4 ± 9.4 | 11 | 67.2 ± 15.4 | 7 | 58.6 ± 16.2 |

### 4.3.3 Temperature relationships when fed chipped wheat plus white clover

When chipped wheat (No. 2) was offered with white clover, 16% of porina fed on wheat only and no porina fed only on clover. Figures 3 & 4 show the relationship between temperature and the amount of wheat and clover eaten over 2 days and 4 days. A greater fresh weight of wheat was eaten than white clover at all temperatures over both feeding intervals (Table 10). Consumption of both food sources increased with increasing temperature. The result at 15°C over 4 days was anomolous.

The relationships compared favourably with porina feeding on wheat only (Figure 2 ). When fed on wheat only, porina consumed slightly less wheat than when in combination with white clover.

TABLE 10 : Fresh weight (mg ± SE ) of wheat (No. 2) and white clover consumed in petri dishes, when offered together to porina at various temperatures (after 2 days and 4 days).

| Temperature (°C) | Paired foods offered | Number of days: 2 days | 4 days |
|---|---|---|---|
| -2 | Wheat | 0.5 ± 0.2 | 3.5 ± 0.7 |
| | Clover | 0.9 ± 0.3 | 1.5 ± 0.8 |
| 5 | Wheat | 16.6 ± 4.2 | 15.9 ± 5.6 |
| | Clover | 2.6 ± 0.5 | 5.8 ± 1.4 |
| 10 | Wheat | 21.3 ± 2.3 | 28.5 ± 2.2 |
| | Clover | 3.7 ± 0.9 | 10.1 ± 3.2 |
| 15 | Wheat | 23.9 ± 6.9 | 45.9 ± 12.1 |
| | Clover | 5.5 ± 1.9 | 5.7 ± 12.1 |
| 20 | Wheat | 28.4 ± 6.5 | 56.9 ± 18.4 |
| | Clover | 6.4 ± 1.4 | 25.8 ± 7.1 |

4.3.4 Acceptability of mixed food sources.

The acceptability of chipped wheat in the presence of cut foliage (white clover or perennial ryegrass) and of the two plant species when offered together in the absence of wheat, was assessed after 2 days and 4 day periods at 15°C. (Table 11).

The results indicate that wheat is an acceptable food source. More wheat than total foliage of both plant species was eaten (Figure 5 ) when white clover and perennial ryegrass was offered together, a larger total weight of food was consumed than where wheat and foliage of either plant was offered. Ryegrass was slightly more preferred than white clover.

TABLE 11: Fresh weight (mg ± SE) of wheat (No.2), white clover and perennial ryegrass consumed, when offered in pairs, at 15°C (after 2 days and 4 days)

| Paired foods offered | Number of days 2 days | 4 days |
|---|---|---|
| Wheat | 23.9 ± 8.5 | 45.9 ± 8.8 |
| Wheat clover | 5.5 ± 1.9 | 5.7 ± 2.3 |
| Wheat | 28.6 ± 4.8 | 30.9 ± 6.2 |
| Perennial Ryegrass | 10.5 ± 2.5 | 16.9 ± 3.6 |
| Clover | 12.7 ± 2.4 | 23.8 ± 7.1 |
| Perennial Ryegrass | 29.0 ± 9.0 | 48.8 ± 12.2 |

### 4.3.5 Faecal counts

Faecal numbers generally increased with increasing amounts of food eaten. However, numbers were erratic and standard errors were large, probably because these pellets were extremely difficult to count accurately after the porina had been feeding, moving about and webbing inside the petri dishes. An example of faecal pellet numbers related to porina feeding on wheat (No. 2),is shown is the Appendix.

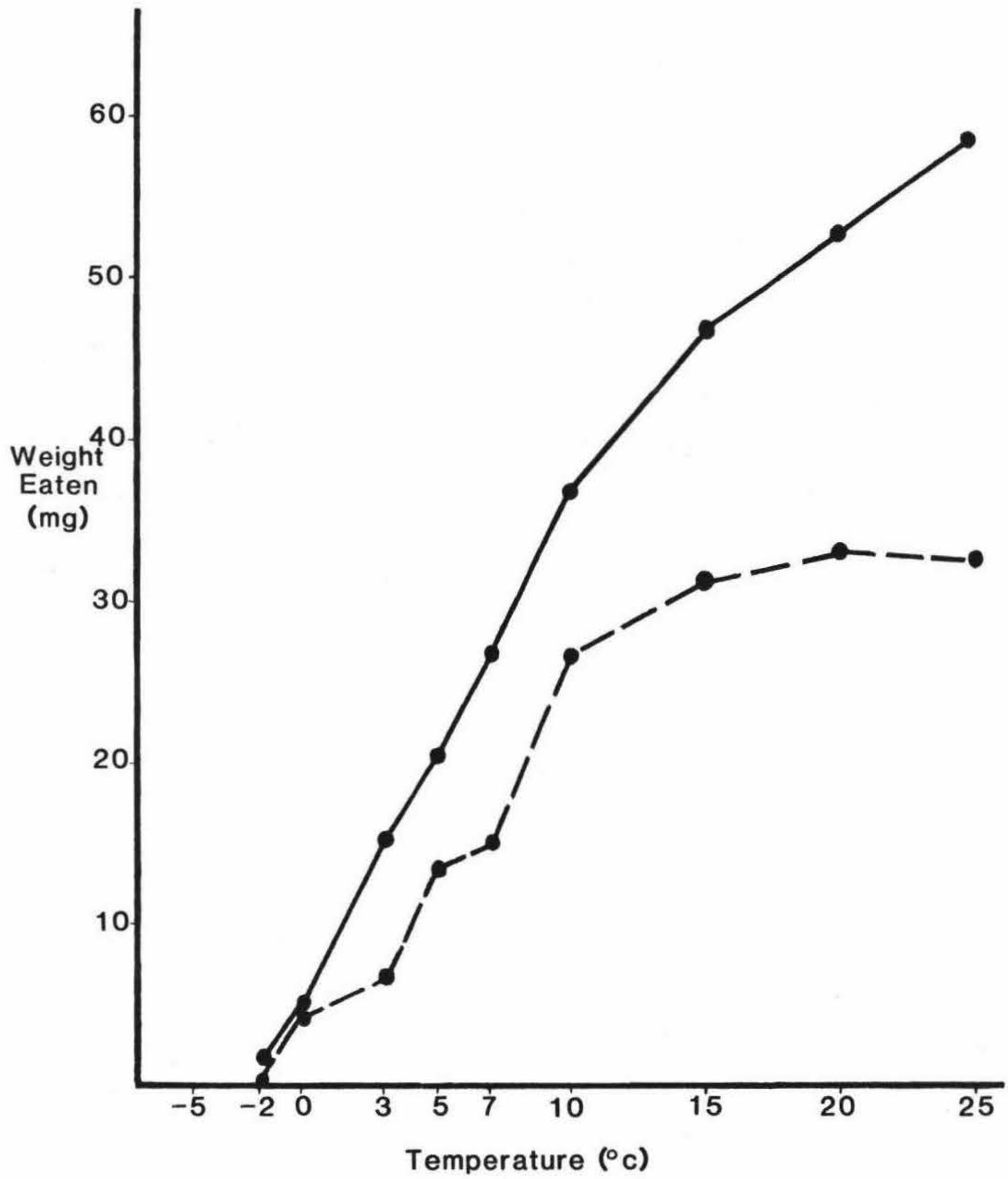


Figure 2: The relationship between temperature and consumption for wheat (Size No. 2) by porina larvae in petri dishes over 2 days (— — -) and 4 days (——).

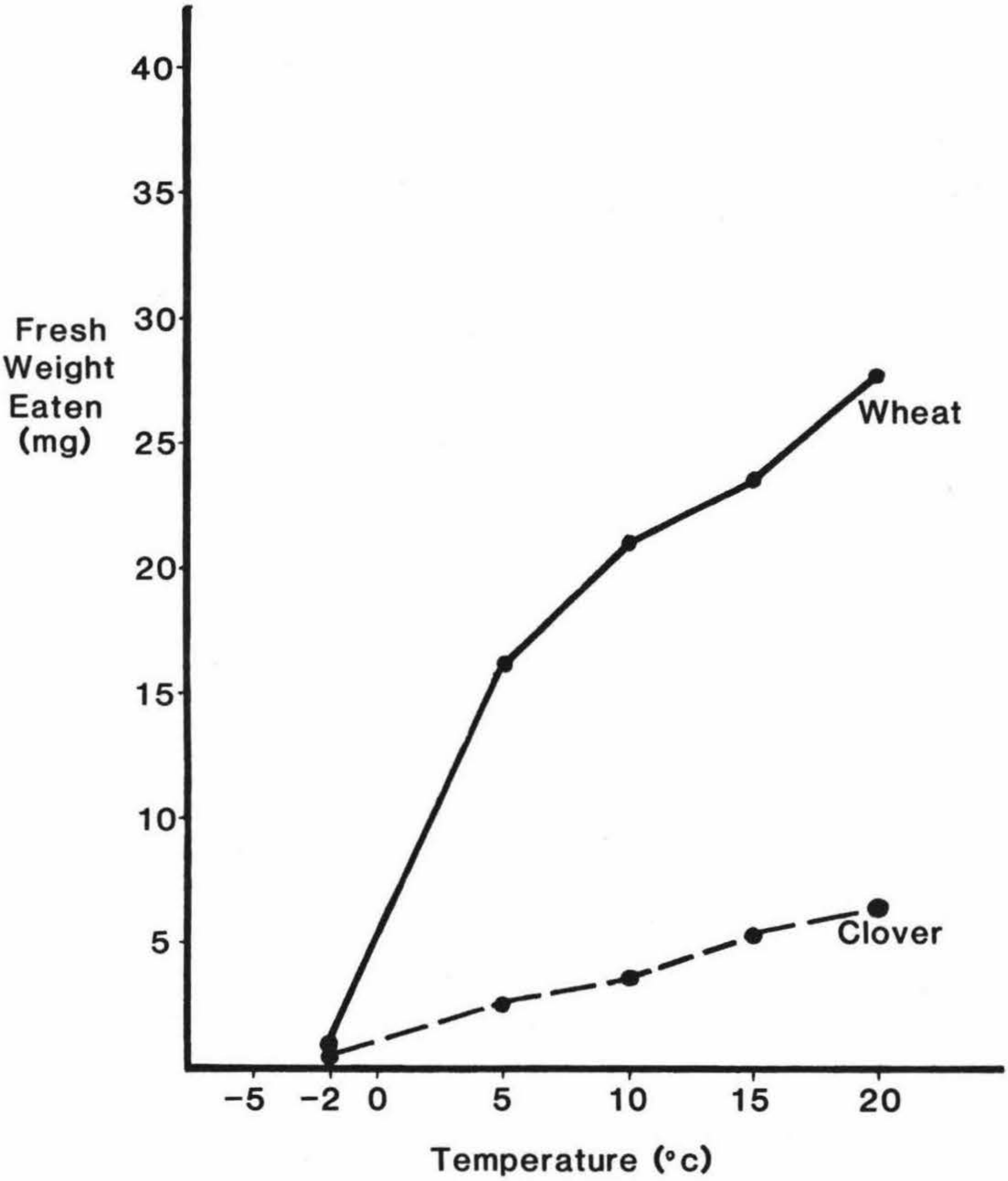


Figure 3: The relationship between temperature and consumption by porina larvae in petri dishes over two days of wheat (No. 2) (——) and white clover (— —).

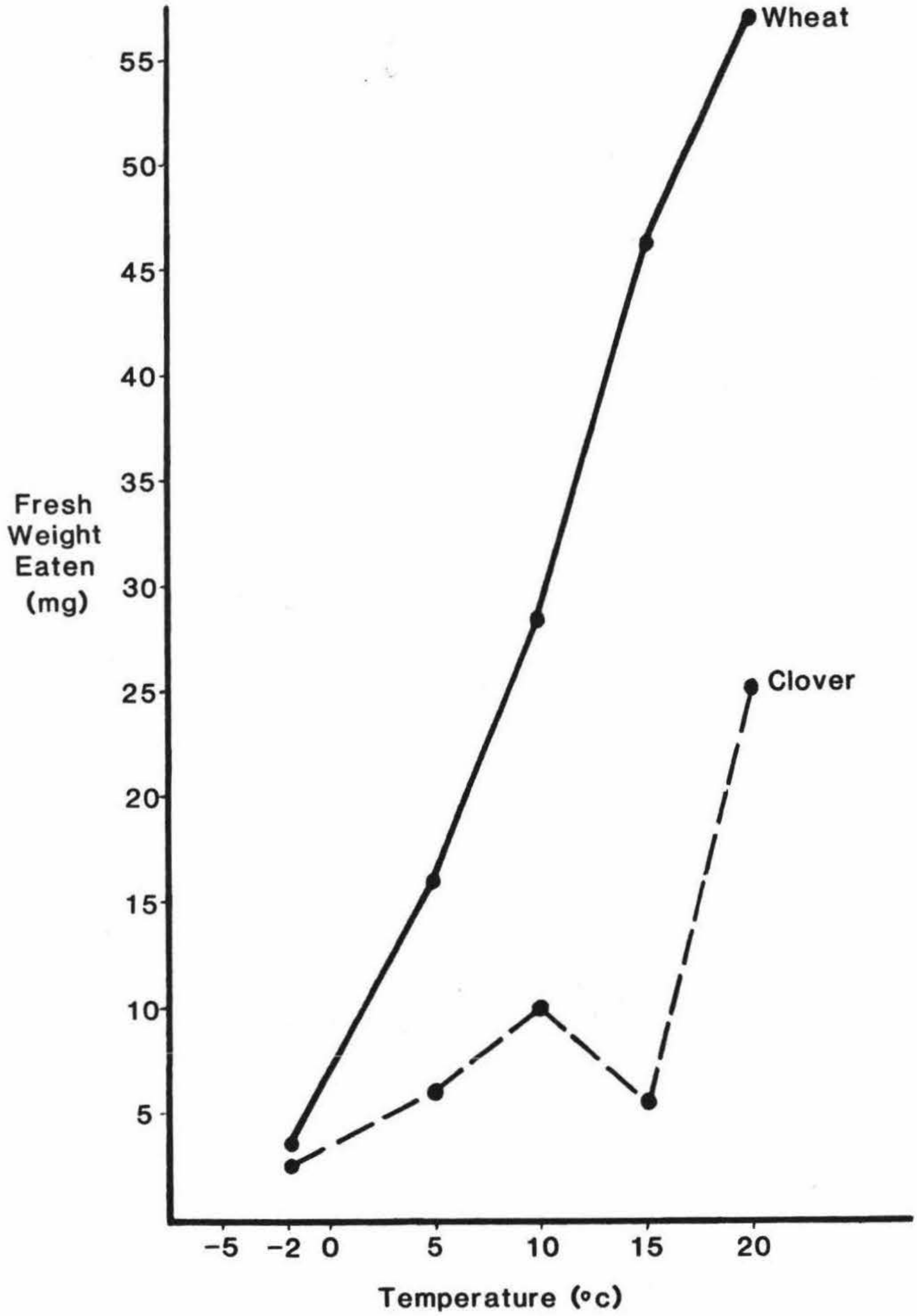


Figure 4: The relationship between temperature and consumption by porina larvae in petri dishes over four days, of wheat (No. 2) (———) and white clover (— —).

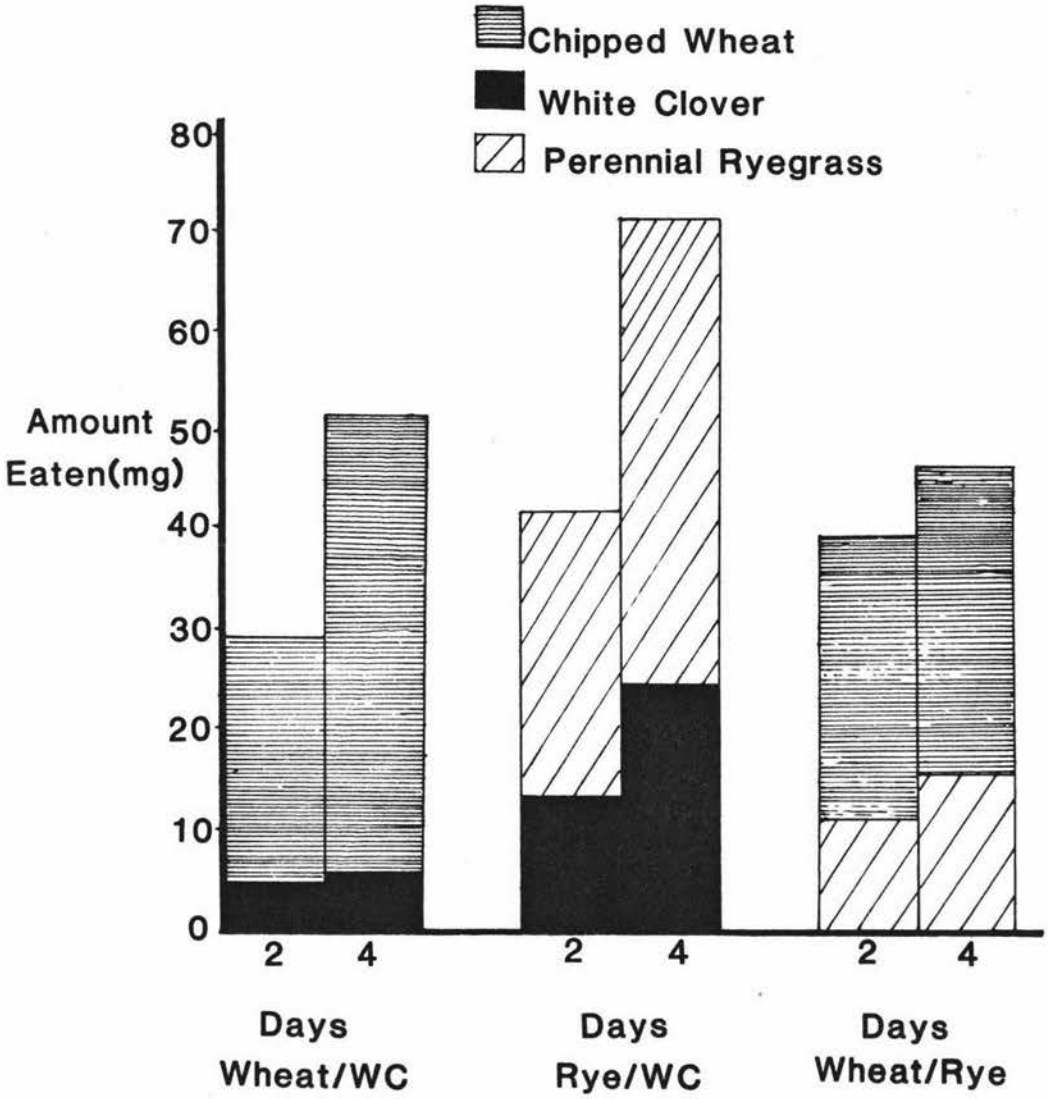


Figure 5: The amounts eaten by porina larvae of three food sources offered in pairs in petri dishes at 15°C, over two and four days.

- chipped wheat and white clover (Trifolium repens L.)
- perennial ryegrass (Lolium perenne L.) and white clover.
- chipped wheat and perennial ryegrass.

# CHAPTER FIVE

## LUNCH-BOX FEEDING STUDIES

### 5.1 INTRODUCTION

Resistance of some pasture plants to feeding by porina has been established. In the field, this has been shown by growth and survival differences, in pasture species under attack, and in the porina infesting them(Harris 1969, Farrell 1976). In the laboratory, measuring the mortality and weight gain of caterpillars fed on different foliage, has revealed varying levels of resistance in pasture species (Farrell et. al. 1974). However the acceptance of different 'resistant' pasture species in feeding trials (Kain et. al. 1979) indicates that porina may feed at random. Harris (1966) reported that greater survival of caterpillars under white clover and cocksfoot (Dactylis glomerata) compared with perennial ryegrass, was due to differences in the availability of herbage to the larvae in their feeding zone. Observations, in the field, of the contents of food caches in burrows indicate that a wide range of foliage is eaten and that this appears to relate to the abundance of available foods. Therefore porina may feed relatively randomly.

It is important to know if wheat baits are actively preferred, are selected at random, or are disregarded, in the presence of foliage. In petri dish trials porina were given both foliage and wheat in confined conditions, and the weight eaten was measured. However to gain additional knowledge on preferences, these experiments were designed to determine if porina could be attracted to, and show an active response in the removing and eating of different food sources, namely wheat baits and pasture species.

### 5.2 SPECIAL METHODS

The specially designed lunch-box feeding containers, as described in the general methods (Page 10) were used in these experiments. All trials were conducted at 15°C, in complete darkness. White clover (Trifolium repens L.), perennial ryegrass (Lolium perenne L.) and size No. 2 of untreated, fungus infected and fenitrothion treated chipped wheat baits were used. Porina were collected from Hauorongo field research area in May 1980 and stored at 7°C. Fresh foliage was collected from the field when needed, ryegrass being cut into lengths and clover separated into uniformly sized leaves.

These gave consistent amounts of each food, which favourably compared in size to each other. Two days were allowed for the larvae to 'settle in', in which time they were fed clover leaves. Trials each lasted two days, whereupon the number of caches and type of food removed, and minor observations were recorded.

A set of boxes were given one treatment, repeated until it was considered enough replicates had been done. Each caterpillar's preference arena was marked to allow observations on individual feeding behaviour, and to check if individuals varied markedly from overall trends. Between each 2-day interval, dead larvae were removed and replaced by healthy ones, general maintenance and watering was carried out, and fresh food was supplied. Porina could be checked easily and without disturbing them too much, by simply lifting up the polystyrene hide, until they could be identified as dead or alive. If Metarrhizium was used and porina had died, the cadaver was removed, and the box rinsed with 50% ethyl alcohol and allowed to dry before replacing the caterpillar. In the fenitrothion treatment larvae still alive but showing typical chronic signs of insecticidal poisoning were taken as dead.

Treatments were as follows:

1. Untreated wheat versus white clover.
2. Untreated wheat versus perennial ryegrass.
3. Metarrhizium infected wheat versus white clover.
4. Metarrhizium treated wheat versus untreated wheat.
5. Fenitrothion treated wheat versus untreated wheat.

### 5.2.1 Analysis of results

Feeding results were listed as in Table 12 , from recording sheets. Before pooling, data were checked for major discrepancies between individual feeding preferences, and between replications. Chi-squared analysis was used to assess overall feeding in each treatment for significant preferences between the foods offered.

## 5.3 RESULTS

### 5.3.1 General observations

Porina freely inhabited the polystyrene hides, and modified them considerably. This consisted mainly of burrowing into the material, and depositing amounts of webbed frass and debris, including polystyrene, filter paper, pith and pins at the exit hole. Most shelters were replaced at least once. Survival in untreated boxes was high; a survival rate in the mid to high ninety percent range was observed.

After a short acclimatization period, porina accepted food from the pins. Activity of individuals was sporadic and contained periods of feeding and non-feeding; consistent patterns were not the rule. (Appendix TWO). There was no evidence for individual porina showing marked differences in preferences from the general trends. Disappearance of food from adjacent sites was not more common than from non-adjacent sites, indicating that items were removed individually and taken away before another selection was made. The untreated food removed was seldom left outside the hide and little was left uneaten. This latter point shows a deviation from the natural field situation where an amount of food is stored. There were no signs of food being partly eaten while still remaining on the pins.

Webbing and modification in the arena by the larvae, gave a good indication of its state of health. It was common for pith to either be chewed or completely eaten, and for micropins to be removed and found, less attached food, in the webbing at the hide entrance or inside. Large pins were also removed. Unhealthy larvae did not show these signs. Visual moulting periods of individuals were short and did not appear to interfere with feeding activity a great deal. A period of inactivity for approximately a day was noticed. The head capsule and sometimes the exoskeletal remains were found in the webbing, as evidence of moulting.

5.3.2 Preference between wheat and white clover

There was no statistical difference ($p \approx 0.2$) (Appendix THREE) between the numbers of white clover and wheat items taken ( Table 12 ). The trend, however did show that more clovers were taken overall, which may have been due to chance, a slight difference in accessibility of the food source or to a slight preference.

Of the 130 representatives 42.6% did not show feeding activity in any one day. The trend showed that most larvae had one or a series of non-feeding periods, which were not directly related to moulting. Of the individuals in non-feeding periods 83.1% were healthy, 11.3% had died, 1.9% were unhealthy and 3.7% had obviously moulted.

The number of arenas in which clover only was taken, was markedly higher than those taking wheat only (Figure 7a). 31% of individuals removed equal numbers of each, and the percentage of individuals removing more wheat than clover and vice versa was the same.

One, two and three items were taken the most often. (Figure 6b) The high value for 'all items removed', probably indicates that this category contained some individuals which would have accepted more food if this was available.

5.3.3 Preference between wheat and perennial ryegrass

There was no statistical differences ($p \approx 0.2$) between the numbers of perennial ryegrass and wheat items taken. Ryegrass had a small advantage over wheat. (Table 12). The feeding classes differs from those of white clover and wheat (Figure 7b). Relatively more equal amounts of ryegrass and wheat were taken, which reflects the increased number of times that six food items were removed (Figure 6a). The lower relative removal of two and three items, in the ryegrass and wheat over the clover and wheat indicates that larvae were taking more. The average number of items taken per individual when feeding on ryegrass and wheat was 4.4, compared to 3.1 for clover and wheat. A lower percentage (34.5%) of non-feeding individuals was seen in the ryegrass and wheat tests and the reason for this is not evident. Individual feeding behaviour was again sporadic (Appendix Two).

5.3.4 Preference between Metarrhizium infected and untreated wheat

From only 32 replicates it was clear that Metarrhizium infected wheat is not preferred (Table 12). Only 2 chips of infected wheat was removed when offered with untreated wheat. Neither of these were taken by themselves (Figure 8a). A chi-squared test revealed a significant difference ($p \approx 0.001$). It can therefore be concluded that porina make a definite selection for untreated wheats. The 37.5% non-feeding arenas compares favourably with the results from untreated preference tests. (Figure 6a b).

5.3.5 Preference between Metarrhizium treated wheat and white clover

A preference for clover leaves over Metarrhizium treated wheat was found to be significant ($p \approx 0.04$). Of the 29 replicates, 27.6% did not show feeding activity, which is slightly lower than that found in other trials. (Figure 6a b). Porina did feed on infected wheat (Table 12 ) but took more combinations with clover predominating (Figure 8b ).

All porina which accepted Metarrhizium infected baits died within eleven days. The typical white and then green bloom appeared after this.

5.3.6 Preference between fenitrothion treated and untreated wheat.

The acceptance of wheat baits was not significantly different ($p \approx 0.3$) from baits treated with fenitrothion and vegetable oil, at the dosage rate used (Figure 8c ). From 40 replicates 52.5% mortality occurred and 47.4% of these replicates did not have bait removed. Since fenitrothion is not considered to have significant fumigant qualities, some of the dead caterpillars which took no food must have been affected by contact with treated baits. All porina which took wheat had died, and only in one case was there more than one wheat removed. (Figure 8c ). This implies that the dosage on fresh bait was high enough to cause mortality when eaten, but sufficiently low to remain acceptable.

TABLE 12: Number of food caches taken by porina when offered a choice between two foods (after 2 days at 15°C).

| Foods offered | Number Taken | | Replicates |
|---|---|---|---|
| Untreated wheat and white clover | 106 | 125 | 130 |
| Untreated wheat and perennial ryegrass | 278 | 305 | 206 |
| Untreated wheat and fenitrothion treated wheat | 48 | 40 | 40 |
| Untreated wheat and Metarrhizium infected wheat | 30 | 2 | 32 |
| White clover and Metarrhizium infected wheat | 45 | 27 | 29 |

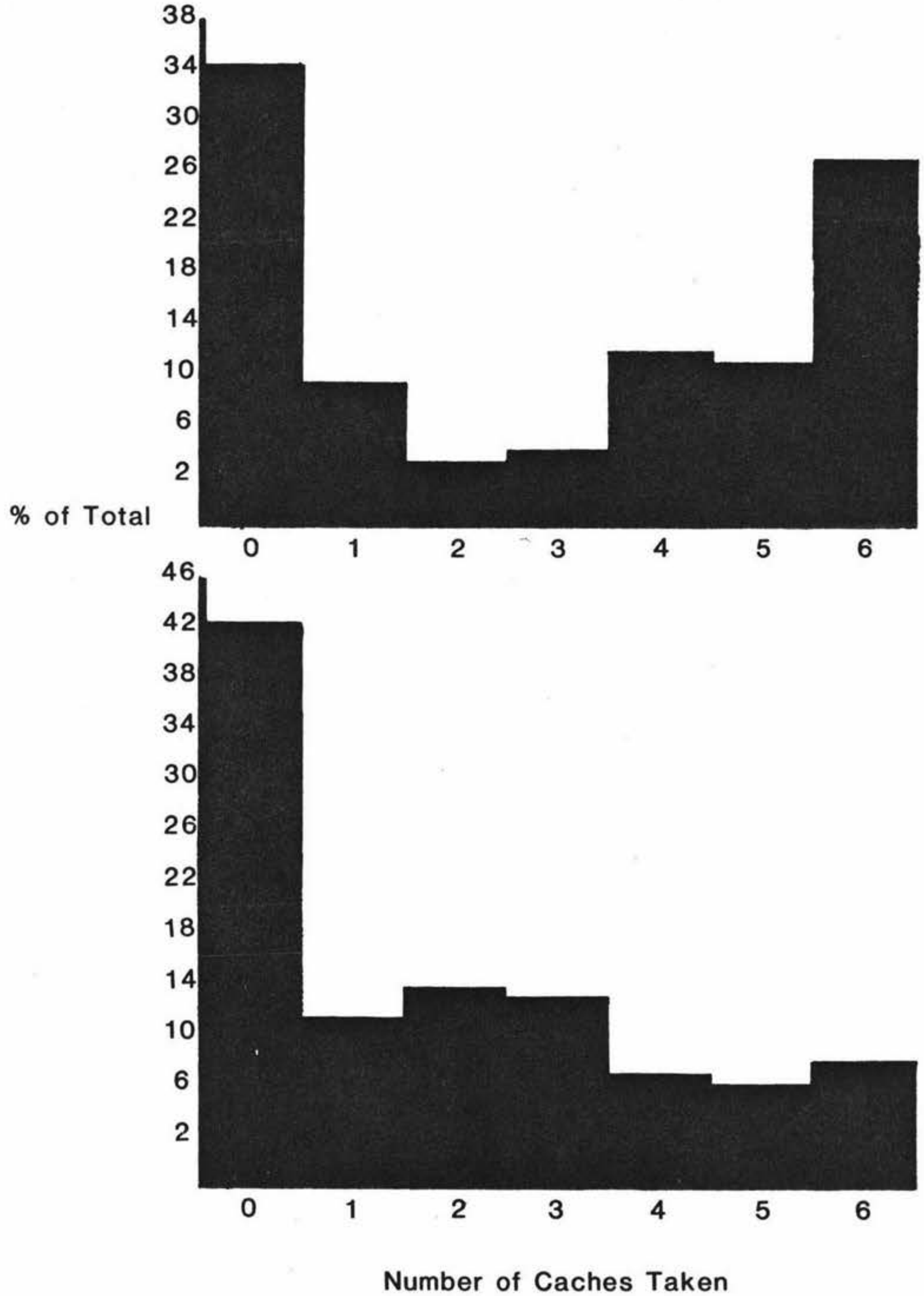


Figure 6: The percentage of replicates and the total number of food caches taken by porina larvae in each lunch box arena at 15°C, after two days.

(a) Wheat bait (size No.2) and perennial ryegrass trials.

(b) Wheat bait and white clover trials.

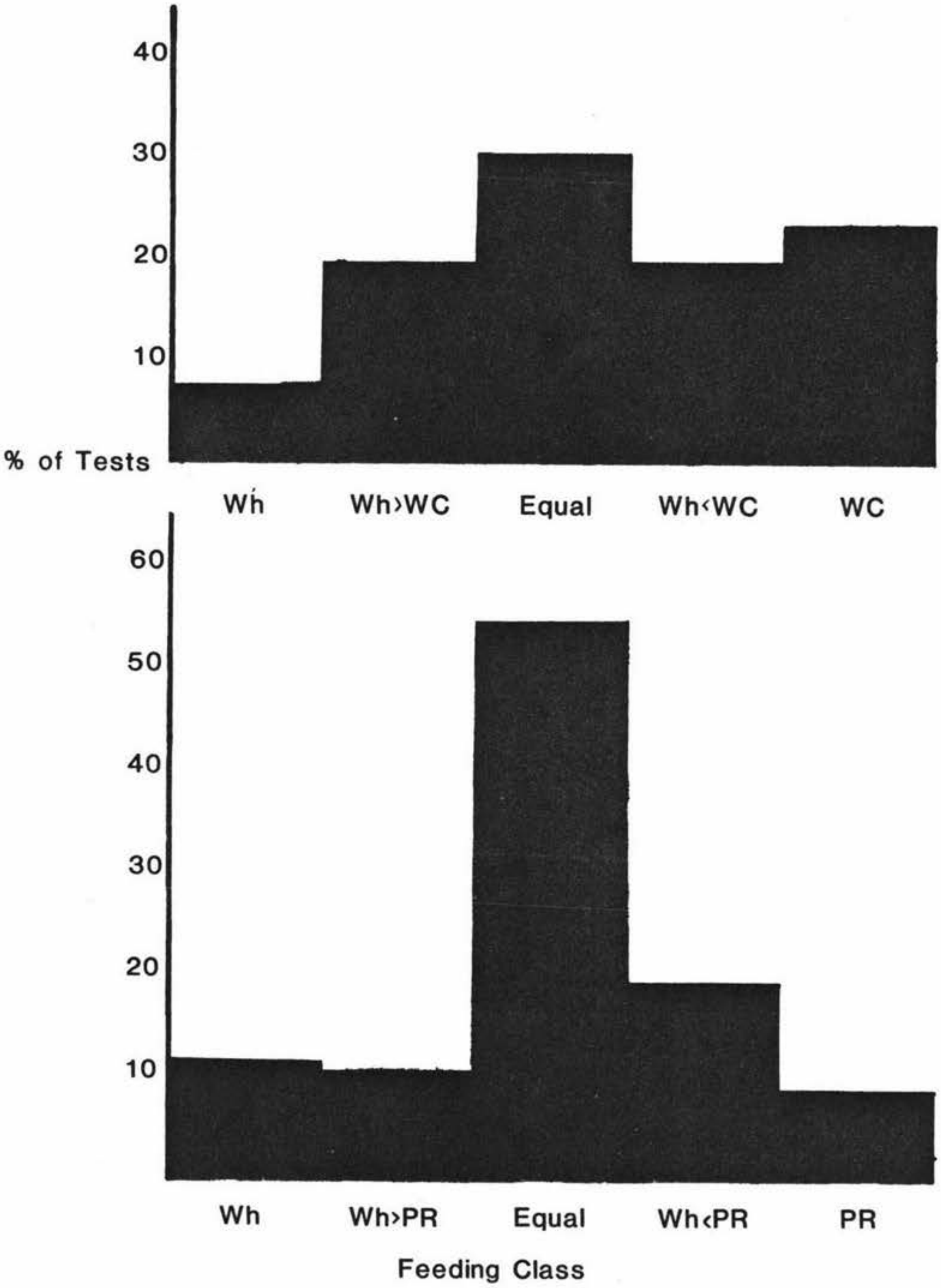


Figure 7: The percentage of replicates and the class* of porina larval feeding in lunchbox arenas at 15°C after two days.

(a) Wheat bait (size No.2) (Wh) and White Clover (WC) trials.

(b) Wheat bait (Wh) and perennial ryegrass (PR) trials.

* Class feeding; a single abbreviation indicates that only that food was taken, a double abbreviation, indicates that two foods were taken in equal amounts (as indicated), and an 'equal' indicates that both foods were taken in equal numbers.

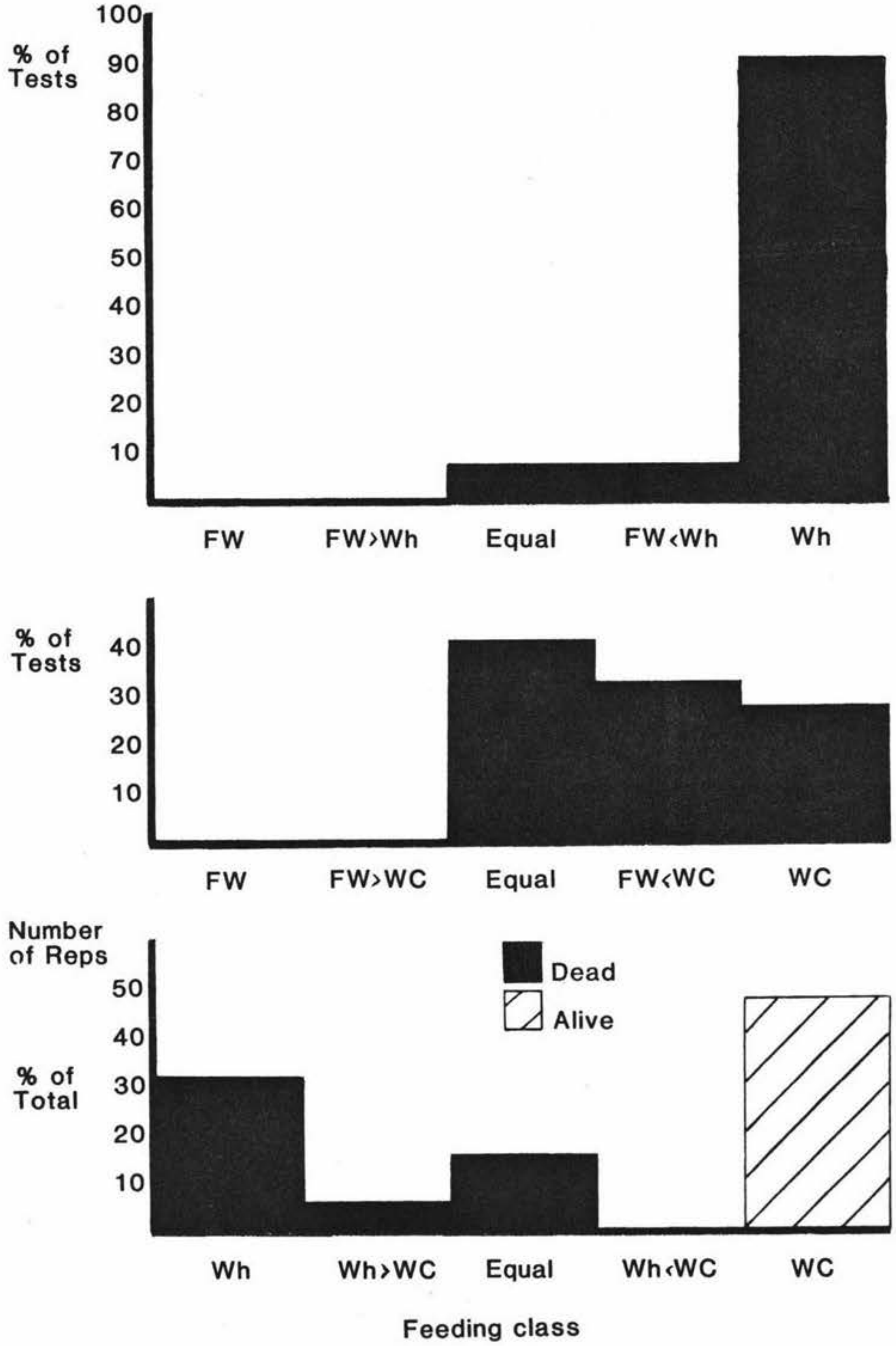


Figure 8: The percentage of replicates and the class* of porina larval feeding in lunch box arenas, at 15°C after two days.

(a) Metarrhizium infected Wheat (FW) and untreated wheat (wh.)

(b) Metarrhizium infected wheat (FW) and white clover (wc).

(c) Fenitrothion treated wheat (Wh.) and white clover (wc.) Shading indicates the health of the porina.

* Class of feeding; a single abbreviation indicates that only that food was taken, a double abbreviation indicates that two foods were taken in unequal amounts (as indicated) and an equal indicates that both foods were taken in regular amounts.

# CHAPTER SIX

## ACCEPTANCE OF BAITS UNDER CONTROLLED NATURAL CONDITIONS.

### 6.1 INTRODUCTION

It is extremely useful to study the feeding behaviour of an insect pest such as porina, under semi-controlled environmental conditions, whilst retaining as much of the natural habitat as possible. Knowing the precise conditions and the insects' reactions, an investigator is able to predict the effect of artificial and natural changes on an insect in its normal habitat. For example, when an impending control procedure, that requires the insect to feed, is being tested, it is advantageous to know the effects that some climatic changes may have on foraging behaviour. The information can then be used to understand the possible reasons for success or failure in the field, and the technique can be modified for optimum results. When dealing with porina, its soil inhabiting nature and above ground feeding activity allows a small population to be removed relatively undisturbed in a piece of its surrounding habitat and placed in controlled conditions, to be studied for removal of food material from the surface.

A method for the removal and storage of large pasture turfs in bins has been developed (W. M. Kain pers. comm.). These steel bins hold field collected 1 m x 0.7 m x 0.3 m deep porina-infested turfs, which are placed in large climatically controlled rooms. The feeding behaviour of porina on baits can be studied by placing baits on the surface and noting their disappearance. The three main advantages of using this method compared to field studies are:

1. Climatic conditions can be modified.
2. Porina are relatively undisturbed.
3. The application of fresh bait, removal of old baits, and observations on feeding behaviour of individual porina is simplified and more convenient than in the field.

However since the bins are time-consuming to collect and transport, untreated rather than treated baits were used to enable replication of trials. Also some natural environmental factors are lost. This technique is a convenient method which allows some questions on bait acceptance to be answered, and which bridges the gap between laboratory experimentation with individuals and field trials with populations.

The two major objectives of this study were to assess the acceptability of baits of different sizes and densities to porina, and relate this to temperature differences. Also since porina have been suggested to only feed a body length from their feeding tunnels (Esson 1970), it is important to know at what application rate porina will come into contact and remove baits with foliage present. Baits may be selected at random, as indicated by feeding studies (Kain et al 1979), or may be actively sought out, or ignored. The ambient temperature could also affect the acceptability of baits. Once these questions are answered, a direct comparison can be made to insecticidally treated baits laid in the field.

## 6.2 SPECIAL METHODS

Nine turf bins were filled with infested turf, in early May 1980 in Taranaki (T.A.R.S.), and transported to Palmerston North. Three each were placed in growth rooms at 12°C, 16°C and 20°C. The day length was set to that of the outdoors, and bins were watered every two days. Before trials commenced each bin was split into four, using 30 cm deep 'fibrolite' sheets sunk into the surface 2 cms giving 12 blocks per growth room. Burrows were identified after vacuuming the surface, marked with small nails, and their location recorded by overlaying a grid. Dyed untreated chipped wheat of the three standard sizes, was spread individually through specially made grids at densities of one bait per 6.5 $cm^2$, 12.5 $cm^2$, 25 $cm^2$ and 50 $cm^2$. At each temperature there were therefore twelve treatments. After four days the numbers of baits removed and active burrows were recorded, and the surface vacuumed to remove the remaining wheat. Four replicates were taken, with treatments being allocated blocks initially at random, and then this order being rotated within each bin, with each new trial.

The numbers and weights of baits removed in relation to size and temperature were graphed, and other relevant observations were recorded. Since plots were selected at random, the burrow numbers per treatment were not taken into account when the results were graphed. A check did not reveal significant differences in numbers between each replicated treatment, or also between different temperatures or bins.

## 6.3 RESULTS

### 6.3.1 General

The mean number of porina per block was 10.3 ± 3.2. Baits were removed, and a distinct pattern of removals near active burrow mouths was seen. Some burrows remained inactive for several days and baits closest to burrows were not always taken, wheat further away being preferred. During the course of the study, a number of caterpillars had dug new burrows in different positions, or had opened new entrances. A small number had excavated new burrows in the soft fill at the ends of bins. The larvae were not generally seen walking on the surface in the daytime, however lone porina was seen on two occasions completely out of their burrows.

### 6.3.2 Distance foraged from burrows

Maximum foraging distance from burrows was estimated by counting the number of grid squares between burrow and removed bait of the individual who travelled the maximum distance to remove a bait. One recording was taken per treatment and the results were tabled (Table 13 ). From the standard deviations, no significant ($p < 0.05$) differences between the rates, or temperatures occurred. The distance ranged from 7.1 to 14.4 cms from the burrow openings.

TABLE 13: The maximum distance foraged (CM±SE) from any single burrow, in each bait treatment on undisturbed turf bins in climate rooms (after 4 days)

| Size Number | Rate (One bait/ $cm^2$) | Temperature (°C) 12°C | 16°C | 20°C |
|---|---|---|---|---|
| | 6.5 | 12.8 ± 4.1 | 12.3 ± 6.0 | 17.0 ± 3.8 |
| ONE | 12.5 | 14.0 ± 7.2 | 14.4 ± 5.4 | 14.4 ± 3.2 |
| | 25.0 | 11.5 ± 4.6 | 9.0 ± 4.0 | 11.0 ± 3.7 |
| | 50 | 12.8 ± 14.0 | 10.7 ± 6.5 | 10.7 ± 10.8 |
| | 6.5 | 9.0 ± 3.8 | 10.5 ± 6.0 | 10.3 ± 6.8 |
| TWO | 12.5 | 7.7 ± 5.4 | 13.3 ± 9.5 | 12.3 ± 3.2 |
| | 25.0 | 9.0 ± 7.6 | 14.0 ± 4.0 | 15.0 ± 6.5 |
| | 50.0 | 14.0 ± 6.5 | 8.5 ± 5.7 | 14.2 ± 13.0 |
| | 6.5 | 11.7 ± 6.8 | 11.3 ± 2.2 | 12.0 ± 8.3 |
| THREE | 12.5 | 7.7 ± 2.2 | 11.2 ± 4.9 | 14.0 ± 4.6 |
| | 25.0 | 10.0 ± 6.5 | 10.0 ± 6.5 | 9.0 ± 10.0 |
| | 50.0 | 7.1 ± 15.9 | 14.2 ± 5.7 | 8.5 ± 5.7 |

6.3.3 Weight and numbers removed, at different rates and temperature.

Mean weights and numbers removed for the four replicates are shown in Tables 14, 15. A trend of decreasing number and weight of baits taken with decreasing density was seen, at all sizes and temperatures. Trends also indicated that numbers of bait chips taken were relatively constant between sizes and that only at the highest density were there consistently more smaller chips than larger, taken Weights taken therefore, increased with increasing size. Numbers and weight of baits of different sizes taken between the three temperatures were relatively constant.

A sharp decline in bait numbers and weight taken was seen between the bait rates of one chip/6.25 $cm^2$ and one chip/1.25 $cm^2$, with lesser declines between the other rates (Figures 9, 10,11). The number of baits taken per active burrow at the three temperatures, seldom dropped below one.

TABLE 14: The mean numbers (X±SE) of baits removed from the surface of undisturbed turf bins in climate rooms (after 4 days)

| Size Number | Rate (One bait/$cm^2$) | Temperature (°C) 12°C | 16°C | 20°C |
|---|---|---|---|---|
| | 6.5 | 64.8 ± 7.4 | 73.1 ± 26.9 | 75.0 ± 24.2 |
| ONE | 12.5 | 24.0 ± 3.4 | 44.8 ± 25.6 | 36.8 ± 6.0 |
| | 25.0 | 15.8 ± 5.7 | 16.3 ± 9.4 | 21.8 ± 16.6 |
| | 50.0 | 9.5 ± 3.3 | 14.0 ± 6.4 | 13.0 ± 9.7 |
| | 6.5 | 40.8 ± 18.0 | 65.0 ± 6.0 | 51.0 ± 38.3 |
| TWO | 12.5 | 24.0 ± 14.8 | 33.0 ± 8.0 | 31.3 ± 14.5 |
| | 25.0 | 14.3 ± 15.1 | 17.3 ± 2.1 | 17.3 ± 3.3 |
| | 50.0 | 6.8 ± 4.8 | 7.5 ± 4.6 | 7.0 ± 2.5 |
| | 6.5 | 57.0 ± 4.3 | 56.8 ± 24.8 | 40.0 ± 20.2 |
| THREE | 12.5 | 25.0 ± 11.3 | 24.8 ± 27.7 | 35.3 ± 13.2 |
| | 25.0 | 12.5 ± 7.0 | 17.8 ± 7.2 | 11.7 ± 5.6 |
| | 50.0 | 7.3 ± 1.6 | 9.3 ± 3.3 | 8.3 ± 7.8 |

TABLE 15: The weight (mg ± SE 95%) of baits removed from the surface of undisturbed turf bins in climate rooms (after 4 days)

| Size | Rate (One bait/cm$^2$) | Temperature (°C) 12°C | 16°C | 20°C |
|---|---|---|---|---|
| ONE | 6.5 | 17.8 ± 1.4 | 20.3 ± 5.1 | 20.6 ± 4.6 |
| | 12.5 | 6.6 ± 0.6 | 12.3 ± 4.8 | 10.1 ± 1.1 |
| | 25.0 | 4.3 ± 1.1 | 4.5 ± 1.8 | 6.0 ± 3.1 |
| | 50.0 | 2.6 ± 0.6 | 3.8 ± 1.2 | 3.6 ± 0.5 |
| TWO | 6.5 | 26.6 ± 18.3 | 42.5 ± 3.9 | 33.3 ± 25.0 |
| | 12.5 | 15.7 ± 10.3 | 21.6 ± 5.2 | 20.4 ± 9.5 |
| | 25.0 | 9.3 ± 9.9 | 11.3 ± 1.4 | 11.3 ± 2.3 |
| | 50.0 | 4.4 ± 3.1 | 4.9 ± 3.0 | 4.6 ± 3.0 |
| THREE | 6.5 | 62.0 ± 4.7 | 61.7 ± 27.0 | 43.5 ± 22.0 |
| | 12.5 | 27.2 ± 12.2 | 26.9 ± 30.1 | 38.3 ± 14.3 |
| | 25.0 | 13.6 ± 7.6 | 19.3 ± 7.8 | 12.7 ± 6.1 |
| | 50.0 | 7.9 ± 1.7 | 10.1 ± 3.6 | 9.0 ± 8.5 |

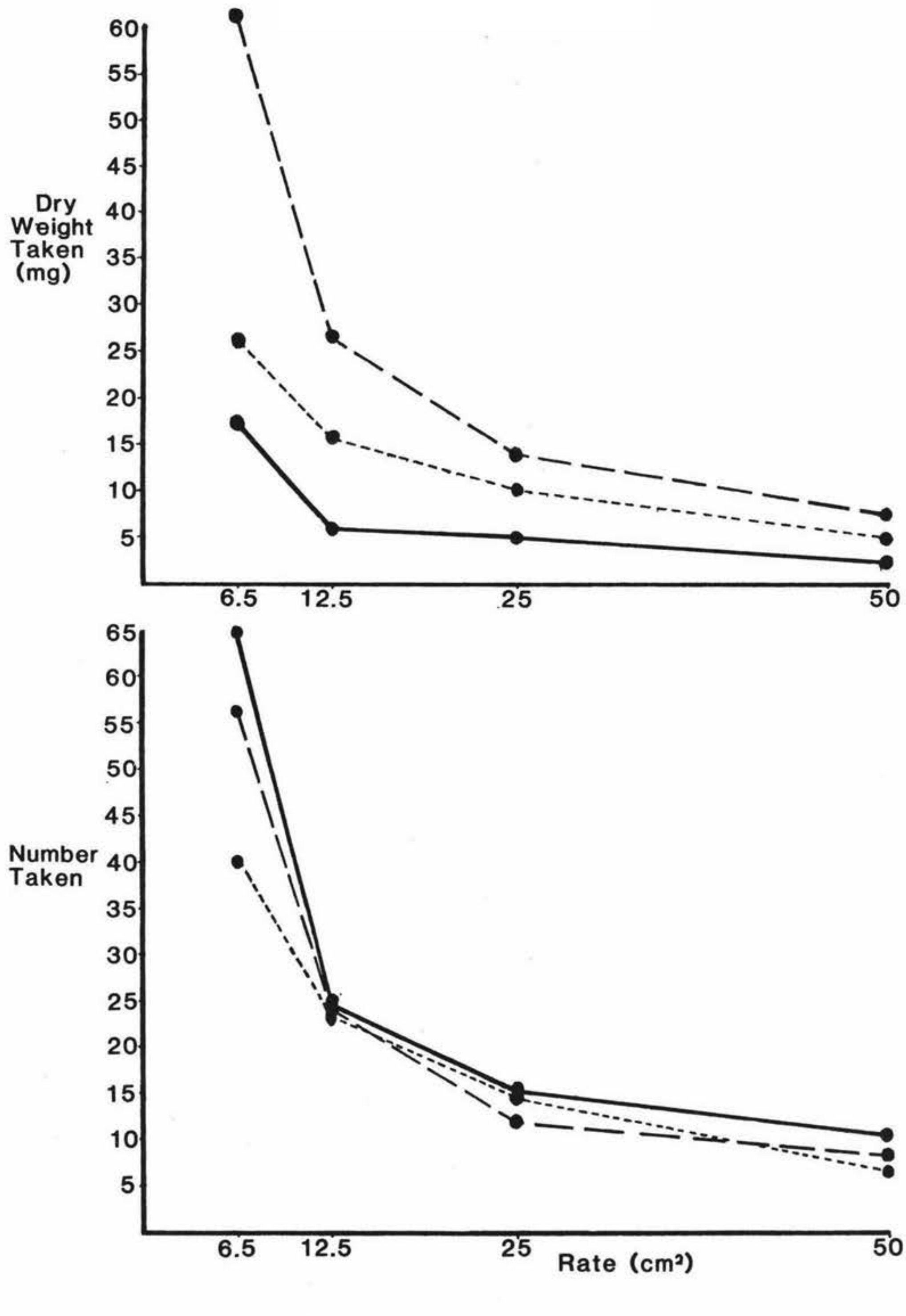


Figure 9: The relationship between (a) the weight and (b) the number, of wheat baits, of three sizes; size No.1 (———) size No. 2 (- - - -) and size No. 3 (— —), removed from the surface of turf in bins by porina larvae after 4 days, at 12°C.

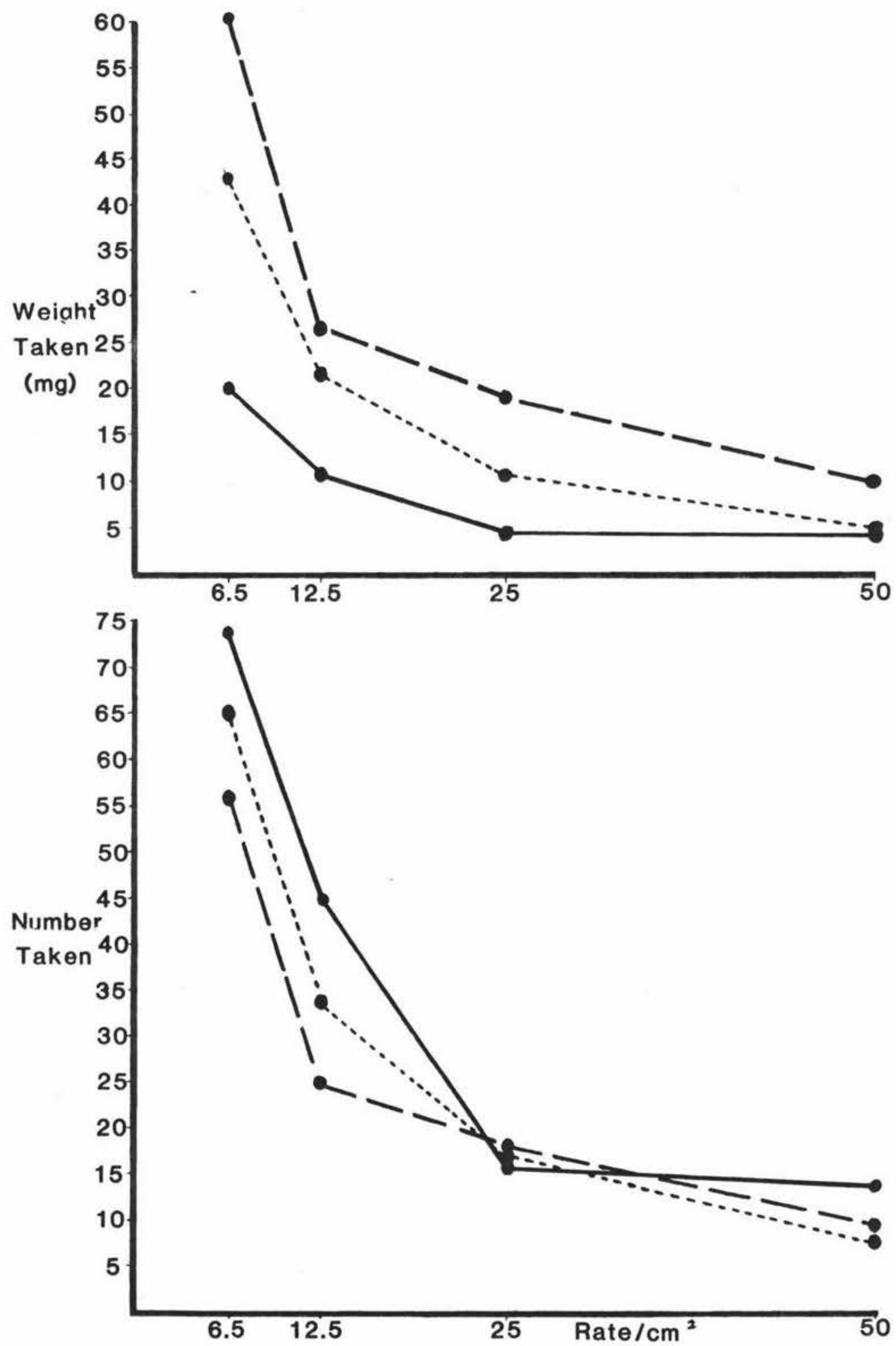


Figure 10: The relationship between (a) the weight of wheat baits and (b) the number of wheat baits, of three sizes; size No.1 (————), size No. 2 (- - - - -) and size No. 3 (—— ——) removed from the surface of turf in bins by porina larvae after 4 days at 16°C.

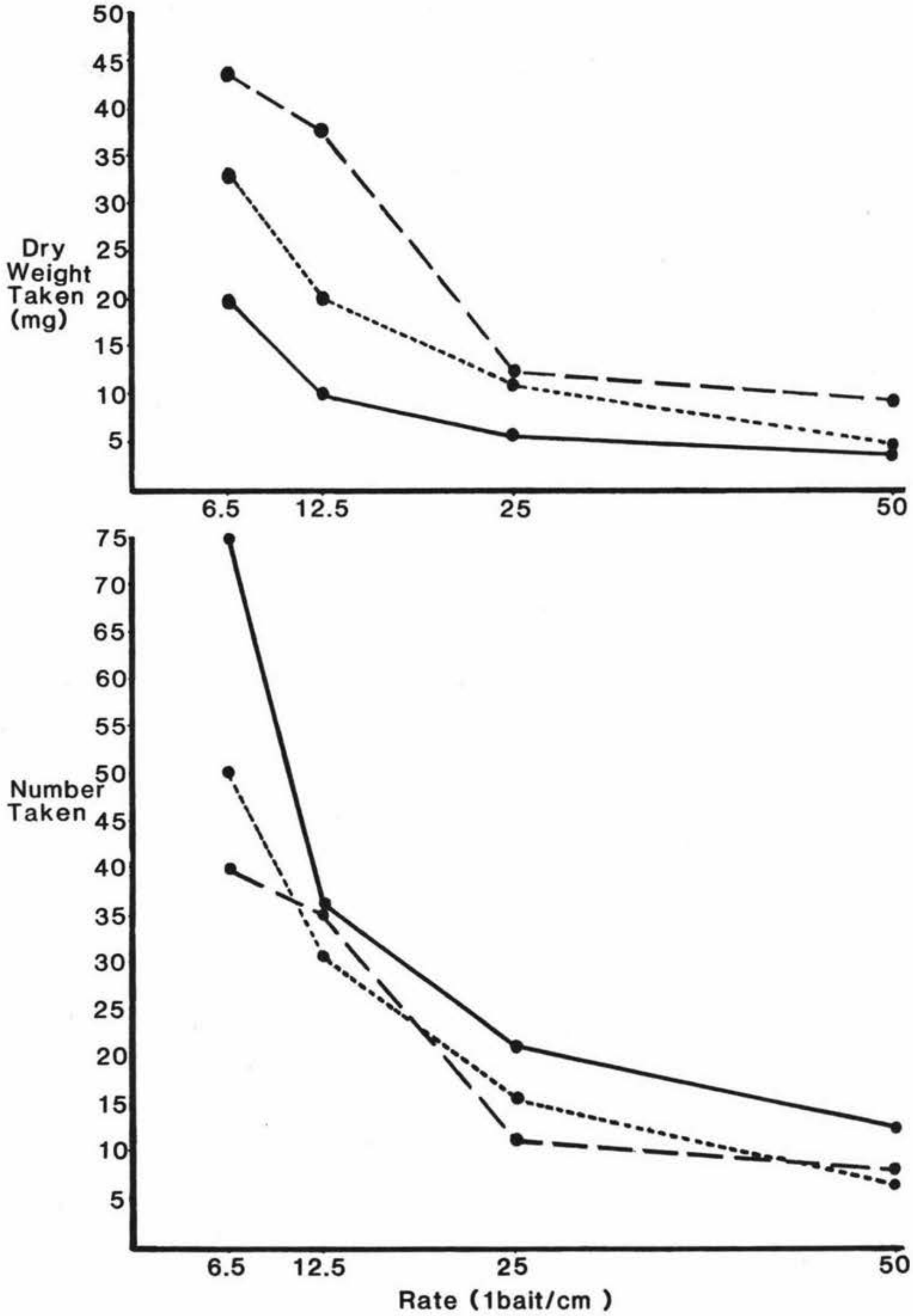


Figure 11: The relationship between (a) the weight of wheat baits and (b) the number of wheat baits, of three sizes; size No.1 (———), size No. 2 (- - - -) and size No. 3 (—— ——) removed from the surface of turf bins by porina larvae after 4 days at 20°C.

# CHAPTER SEVEN

## EFFECTS OF TREATED BAITS ON SLUGS

### 7.1 INTRODUCTION

Introduced slugs are common on most pastures in New Zealand. The theft of insecticidally treated chipped wheat baits by slugs in the field may affect the efficiency of the use of this control method for porina caterpillar. A laboratory trial was designed to test the toxicity to slugs of baits treated with the proposed insecticides and molluscicides used later in the field work. A trial was also conducted to assess the spatial dislodgement of baits when slugs consume them. Deroceras panormitanum and D. reticulatum are the most important slug pests in New Zealand (Barker 1979) and on pastures in the lower North Island these two species are the most abundant. The toxicity of a number of biocides to these slugs has been reported, (Van der Gulik and Springett 1980) and these include two identical and two closely related chemicals to the ones used in this study.

### 7.2 SPECIAL METHODS

The two slug species were collected under logs at the edges of pastures near Massey University, and kept for 48 hours without food before the tests. Slugs were tested for chemical toxicity in polystyrene boxes (47 cm x 31 cm) with a fitting muslin lid, as described by Van Der Gulik and Springett (1980). Each box contained a covered refuge, a floor layer of moist peat, a flat dish containing baits, and thirty mixed-age slugs, fifteen each of D. panormitanum and D. reticulatum.

Six treatments of baits, size No.2, were used (Table 16). All dosage rates were 0.4% a.i./dwt. Baits were given in equal amounts, in excess, and the number of slugs killed after 10 days at ambient temperature recorded. The tests were repeated four times. A one-way analysis of variance between the treatments was carried out, and the 95% confidence limit calculated.

To assess the dislodgement of baits a 30 cm x 25 cm plastic refridgerator tray was lined with moist paper towels and a 7 x 6 grid of 6.25 $cm^2$ squares marked in the centre. Moist rags were placed as refuges around the perimeter of the tray. Untreated dyed baits were placed in the centre of each grid square, and 10 slugs of each species were liberated into the tray. The tray was covered with glass and placed at ambient temperature in the laboratory. Bait dislodgement and condition was recorded after 4 days and the treatment was repeated three times.

## 7.3 RESULTS

### 7.3.1. Bait toxicity

Mortalities of slugs under different treatments are shown in Table 16 .

TABLE 16 : Mean mortality (%) of slugs fed on treated baits (after 10 days)

| Bait treatment | Slug mortality (%) | | |
|---|---|---|---|
| | D.reticulatum | D. panormitanum | Mean |
| Fenitrothion | 21.8 | 18.5 | 20.0 |
| Actellic | 26.8 | 21.5 | 24.1 |
| Vydate | 78.5 | 21.8 | 50.1 |
| Lindane | 11.8 | 8.8 | 10.0 |
| Metaldehyde | 43.5 | 51.8 | 47.6 |
| None (Control) | 11.5 | 13.3 | 12.4 |
| | LSD 5% - 5.2 | | |

All treatments except Lindane, showed a significant ($P < 0.05$) average mortality advantage over the controls. However both fenitrothion and actellic insecticides proved to be only mildly toxic. Vydate gave a consistently large mortality with D. reticulatum only. The molluscicide, metaldehyde, yielded a high mortality with both species.

### 7.3.2 Dislodgement of Baits

No baits were totally eaten; husks or parts of chips remained (Table 17). A low percentage (%) of husks were found outside their respective grid squares, indicating that slugs consuming baits, do not generally move them very far from their original position.

TABLE 17: Dislodgement and condition of untreated baits (after 4 days)

| Condition of bait on grid squares | Percentage (%) of total baits | | | |
|---|---|---|---|---|
| | Rep.1 | Rep.2 | Rep.3 | Mean |
| Husk only remaining | 88.1 | 81.0 | 71.4 | 80.2 |
| Part of grain remaining | 11.9 | 14.3 | 21.4 | 15.9 |
| Missing | 0 | 4.7 | 7.2 | 3.9 |

# CHAPTER EIGHT

## DISCUSSION OF LABORATORY STUDIES

### 8.1 INTRODUCTION

A number of the basic aims of this thesis were answered from laboratory studies. These are discussed and the conclusions integrated into the design of later field experiments.

### 8.2 PETRI DISH FEEDING STUDIES

#### 8.2.1 Feeding relationships.

Porina were shown to eat untreated chipped wheat baits in petri dishes in the laboratory. When offered baits together with either perennial ryegrass or white clover, the foliage has not actively preferred, although a smaller total fresh weight of food was consumed than where the two plant species were offered together. Ryegrass was slightly, but not significantly preferable to white clover. Significant differences ($p \geqslant 0.05$) however did occur in the extra weight of wheat than ryegrass or clover taken when the foliage species were offered with the baits. This may be related to factors, other than an active porina preference for wheat, such as the density difference between these two food types, which may encourage the caterpillar to consume a greater weight of wheat. It is therefore shown that porina eat more wheat, but it is not shown that porina will actively select wheat in favour of ryegrass or white clover. However it is clear that wheat is an acceptable and adequate food source.

An increase in temperature led predictably to an increase in consumption of bait. However the maximum and minimum temperatures where feeding occurred on wheat were surprising. Over a two day period the maximum rate of feeding occured at 25°C and the minimum at -2°C. At typical field temperatures, bait consumption should therefore only be adversely affected on frosty mornings, when larvae in the field are known not to feed (Esson 1970) probaly due to inhibition of larval emergence by the low temperatures. The preference for wheat, even when offered with white clover, was not altered by changes in temperature, and therefore in the field it would be expected that wheat was equally acceptable whatever the temperature.

The size of the wheat chip did not affect the weights of wheat eaten by porina; however slightly fewer of the largest bait size were eaten. This would indicate that porina eat parts of baits and not whole baits in confined conditions especially when the baits are of larger size. These results indicate that there is little selection, in petri dishes, for baits of different sizes.

8.2.2 General observations

A number of incidental observations were made, and some of these warrant a short mention.

Not surprisingly the mortality of porina increased at low temperatures. The lowest sustainable temperature at which total mortality occurs is below -2°C.

Feeding was not inhibited for long periods by ec dysis. However it is probable that these periods are larger than observed, since visual evidence of moulting is seen late in the process.

A high percentage of porina which died had fed before death. Since the treatment periods were relatively short, porina generally must feed up to a short time before death. This may be related to disease or stress characteristics.

8.3 LUNCH-BOX FEEDING STUDIES

8.3.1 Selection of food

These studies were primarily concerned with the identification of definite selection preferences by porina between wheat and two pasture species. Porina do not select untreated wheat any more or less readily than white clover or perennial ryegrass, although slight differences did occur. This is keeping with other workers (Kain et. al. 1979). The choice of baits containing a moderate dosage of fenitrothion, did not show a marked difference to the choice of untreated baits and insecticidally treated wheat, at this dosage, should be consumed in the field.

The choice of fungal infected baits, however may pose a problem in the field situation. Metarrhizium treated wheat was not readily chosen, when offered with untreated wheat. In the presence of white clover the treated baits were chosen more often than when presented with untreated baits, indicating that although Metarrhizium treated wheat is not a preferred food, it is none-the-less consumed.

In the field this could be very important.

### 8.3.2 General observations

Porina are known to be erratic feeders (French 1973 a) and this is seen in these studies. Being placed in total darkness did not have the effect on porina of inhibiting non-feeding periods. (Appendix TWO).

These selection arenas may be very useful for other studies. Important information on bait acceptance, with different carrier substances and insecticides, would be gained.

## 8.4 ACCEPTANCE OF BAITS IN CONTROLLED NATURAL CONDITIONS:

These studies simulated the field situation more closely than the previous experiments, but could not show in detail selection preferences, since only wheat removed from the surface could be recorded. The main conclusions were:

(1) porina removed untreated baits from the pasture surface although foliage was present.

(2) porina choice did not change significantly over the three moderate temperatures of 12°C, 16°C and 20°C.

(3) no more small baits were taken than larger baits, and therefore more weight of large baits were generally taken.

(4) at higher densities more baits were taken, with a sharp increase of baits being taken between one chip/25 $cm^2$ and one chip/6.25 $cm^2$.

(5) the maximum foraging distance from burrows did not alter significantly between the three treatment variables.

## 8.5 THE EFFECT OF TREATED BAITS ON SLUGS:

These results indicate that the only insecticide likely to greatly decrease slug numbers in the field is vydate. The toxicity of this insecticide, is dependent on the slug species and therefore would prove unsatisfactory if slugs of the less susceptible species were present.

Metaldehyde, a molluscicide would be most likely to kill slugs, however this chemical does not have insecticidal properties.

8.6 CONCLUSIONS:

From laboratory work it is clear that porina will readily accept chipped wheat baits over a range of temperatures, with foliage present, and whether they be moderately insecticidally treated or not. This enhances the observation that porina are relatively random feeders (Kain et al 1980). Selection differences were obtained between Metarrhizium infected wheat and uninfected foods, proving that porina do select against some unfavourable food sources (Dumbleton and Dick 1942). Therefore in field work attention must be paid to the acceptance of Metarrhizium baits, and any other types of baits which may be used, but it would be expected that acceptance of insecticidally treated wheat baits would not present difficulties.

Since porina chose about the same number of baits of different sizes, chip size No.1 should be used as the most cost-efficient bait. From other observations it is clear that this size is the smallest a bait can be and, still retain ballistic properties which enable it to be applied evenly, does not degrade or disintegrate too rapidly and holds a lethal dose of insecticide. These observations reflect the reported advantages of a small pelletted bait 'Snylok' used in cutworm control in South Africa, by Safsan Agricultural Chemicals (Pty.) Ltd. (Anon. unpub.). Here particle size is at least 500 particles per gram, and is applied at rates as low as 5 Kg per hectare.

The rate of application is important in the cost of field control of porina by baits. From these laboratory studies, at very low rates of application the consumption of untreated baits average less than one per caterpillar, with the porina here being able to take more than one bait without harmful effects. In field applications for efficient control, a bait take of at least one chip per porina is needed, depending on the toxicity of the insecticide, and therefore the most efficient bait rate would be above one chip/25 $cm^2$. In field trials the use of one chip/6.25 $cm^2$ and one chip/25 $cm^2$ would offer the best chance of obtaining an optimal bait density level, bearing in mind that a relationship between optimal density and optimal damage is important.

The effect of slugs on the removal of baits and therefore porina mortality in the field situation is not known. Slugs do not generally remove wheat baits from their resting place, but do consume all but the outside husks of these. Adding metaldehyde on to field applied chipped wheat, with an insecticide would show what effect slugs have on the efficiency of treated baits.

Metarrhizium infected baits are accepted by porina, although actively selected against. In the field situation this later point may be important, however due to the ineffectiveness of the fungus, the small number accepted may be adequate for control.

Finally, the original aims related to the laboratory studies with untreated wheat baits, and also with some treated baits (page 7 ) was fulfilled in these studies, and field work with treated baits was instigated.

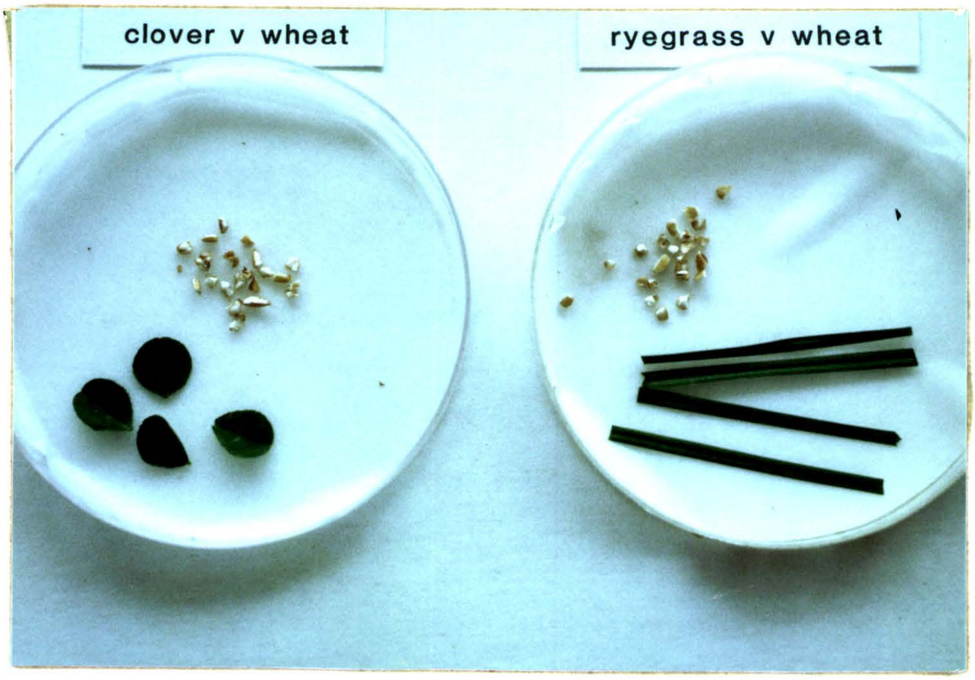


Plate 1: The food types; wheat (No. 2), white clover and perennial ryegrass, used in feeding studies in petri dishes.

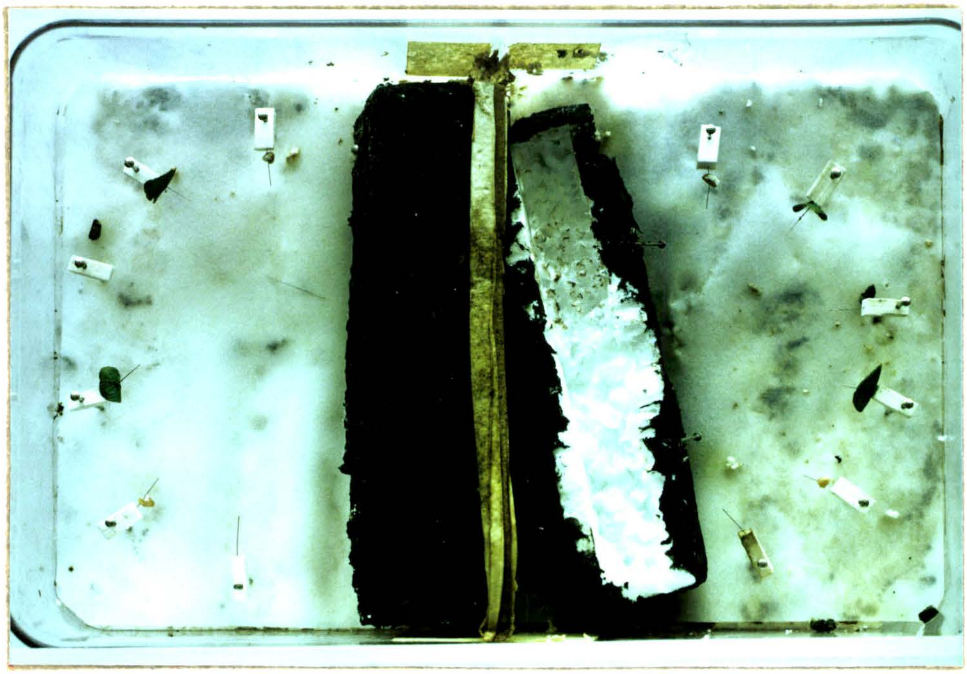

Plate 2: The arenas (two per box) used for lunch-box feeding studies. Note the hollowed polystyrene hide with central exit hole upturned for inspection (right) and the absence of food from some micropins, attached to pith blocks held in position by large pins.

Plate 3: Turf bin used in the studies of bait acceptance under controlled conditions. (before removal to the laboratory).

Plate 4: A Metarrhizium infected larva found in the field.

Plate 5: A small plot field site at Hauorongo.

Plate 6: A large plot field site at Waikanae.

# CHAPTER NINE

## HAUORONGO SMALL PLOT FIELD EXPERIMENTS

### 9.1 INTRODUCTION

Chipped wheat baits were assessed in small plots in the field. These trials was designed to establish the effectiveness of insecticidal and fungal treated baits in controlling natural porina populations.

Questions asked were:

(1) Does application of treated baits in the field result in porina mortality?

(2) What is the relationship between bait density and mortality?

(3) What is the relationship between bait insecticidal dosage and mortality?

(4) What are the comparisons between a conventional spray application of an insecticide, and varying bait treatments?

(5) Does the incorporation of molluscicide in a bait increase its effectiveness?

The previous section, (Section 1) on the behaviour of the caterpillar in relation to bait acceptance, guided the design of these trials. A number of comparisons were made between this laboratory work and field work, some supplying basic background information and others being directly useful. In summary these were to use;

(1) The smallest bait only, of the original three sizes.

(2) Two bait densities, in all but one trial.

(3) Predominantly four insecticides.

Modifications were made to the design throughout the experimental period, to allow refinement or expansion of the basic goals. A single insecticidal dosage was applied on baits used in mortality comparisons between different insecticides and bait densities. This was assessed as being near optimal from the initial dosage trials. Fungal (Metarrhizium anisopliae) treated baits with a low dosage of fenitrothion were included after the initial fungal treatments were indicating that they would give relatively low control. It was considered that the effectivity of Metarrhizium anisopliae (hereafter referred to as Metarrhizium) may be enhanced by the use of a low insecticide dosage on the bait. This dosage is postulated to decrease the natural resistance of the insect to the pathogen.

To extend basic aims, assessments were made of lindane as an insecticide, and sawdust as a carrier rather than wheat. Lindane is a less expensive and more persistent insecticide than fenitrothion, and sawdust is extremely cheap.

## 9.2 EXPERIMENTAL DESIGN

Plots (0.5 m x 0.5 m) were marked with 1 m x 0.14 m, thin, 'fibrolite' sheets sunk 0.03 m into the ground. Four blocks of trials were laid (Table 18,19,20 & 21) and sampled in replicates after 10 day periods except for the two fungal treatments which were sampled after 3 weeks. Plots for each replicate were allocated treatments at random. Samples consisted of 0.45 m x 0. 45 m squares within each plot, leaving a 0.05 m wide buffer zone around the perimeter.

TABLE 18: Treatments for the assessment of the relationship between the insecticide dosage and mortality (3 replicates)

| Chemical & Carrier | | Dosage Kg ai/ha* | (% a.i./g dwt)** | Bait Density (1 chip/$cm^2$)*** |
|---|---|---|---|---|
| Fenitrothion bait | . | 0.025 | (0.08) | |
| | . | 0.05 | (0.17) | |
| | . | 0.1 | (0.33) | 6.25 $cm^2$ |
| | . | 0.2 | (0.66) | |
| | . | 0.3 | (0.99) | |

* Kg ai/ha - Kilograms active ingredient per hectare

** ai/g.dwt - equivalent percentage active ingredient per gram dry weight of wheat chips.

*** 1 chip/$cm^2$ - 1 chip of wheat per varying area ($cm^2$)

TABLE 19: Treatments for the assessment of bait density and porina mortality relationships (3 replicates)

| Treatment & Carrier | | Density (1 chip/$cm^2$) | Dosage (Kg ai/ha) |
|---|---|---|---|
| Fenitrothion bait | - | 6.25 | |
| | - | 12.5 | |
| | - | 25.0 | 0.2 |
| | - | 37.5 | |
| | - | 62.5 | |
| | - | 125.0 | |

TABLE 20: Treatments for the assessment of the relationship between the type of insecticide and carrier, and mortality.

| Carrier | Chemical | Application Rate* | Number of replicates |
|---|---|---|---|
| Spray | . Fenitrothion | 0.9 Kg ai/ha | 12 |
| Bait | . Fenitrothion | (1) | 12 |
| | & Metaldehyde | (2) | 12 |
| | . Actellic | (1) | 12 |
| | | (2) | 12 |
| | . Vydate | (1) | 12 |
| | | (2) | 12 |
| | . Lindane | (1) | 5 |
| | | (2) | 5 |
| | . Sawdust | (1) | 6 |
| | . Nil (control) | (1) | 12 |
| Nil | . —— (control) | - | 12 |

* (1) 0.13 kg ai/ha (1 chip/6.25 $cm^2$)
(2) 0.03 kg ai/ha (1 chip/25$cm^2$)

TABLE 21: Treatments for the assessment of the relationship between Metarrhizium infected baits and mortality.

| Bait Treatment | Rate (1 chip/$cm^2$) | Dosage (Kg ai/ha) | Number of replicates |
|---|---|---|---|
| Metarrhizium | 6.25 | - | 33 |
| Metarrhizium & Fenitrothion | 6.25 | 0.013 | 12 |

9.3 . SPECIAL METHODS

A site on the Hauorongo research area (Page 13) was chosen after a survey of the Palmerston North area for porina infestations. Owing to adverse weather conditions in August and September the plots were covered. 4 metre x 1 metre wire mesh gates were tied together upright to make a rectangular block of 15 metres x 4 metres and plastic tarpaulins were placed over this area and lashed to these gates. Posts were placed under the tarpaulins, along the centre line, as pointed stays, giving a 'tent' effect. This enabled access to the trial site underneath the sheets and the tent to shed rainwater.

Two adjacent 15 m x 4 m sites were used consecutively. Appropriately sized gaps were left between the 0.5 m x 0.5 m plots to enable enough room for access and sampling. Before each sample was taken, the fibrolite sheets were removed and the diggings placed in these gaps for sorting. Surface counts were taken of dead porina in all trials, and also dead slugs and worms in the large trial (Table 20). Numbers of dead and live porina sorted from the 0.45 m square by 30 cm deep soil samples were recorded. Since bird and hedgehog presence under the trial tent was minimized, it was considered that the loss of dead porina from the surface would be insignificant in the analysis of treatment mortalities.

The first two trials were sampled after 72 hours, the main trial after 10 days, and the fungal treated trial after 3 weeks. The trial area was treated and sampled, in a stepwise manner from one end to the other. Because of the time delay Metarrhizium treatments were laid at the opposite end of the area to alleviate contamination, and to allow step-wise sampling to be relatively continuous.

All baits were treated as described on page 8, with the fenitrothion and metaldehyde in combination being applied at the usual concentration of each. Appropriately sized grids were laid on the surface over the plots and each chip was placed individually with forceps in the centre of each square. A small hand held 'Cambrian' sprayer was used for the fenitrothion spray applications.

Sawdust from untreated timber was obtained from a local sawmill. This was selected for its evenness in particle size, (480 particles per gram). Before treatment with insecticide, the sawdust was boiled for two hours and rinsed to extract tannins.

All porina still alive taken back to the laboratory and kept at 20°C in clean petri dishes. This enabled the assessment of weight differences between treatment porina and controls and also the post-development of Metarrhizium infestations in the larvae from the fungal treated plots.

Cover readings of vegetation were recorded for each plot in the main treatment plots (Table 10) by means of a point analyser.

Removal of treated and untreated baits was recorded from some treatment plots. In four of the replicates from each bait treatment in Table 20 , dyed baits were applied, and the disappearance of these recorded after 10 days. In all the fungal treatments and the insecticidally treated sawdust replicates, missing baits were recorded. These were expressed as a percentage of the total baits present in the beginning of the experiment.

Analysis of variance were used to separate the porina mortalities in the insecticide treatments. Student's t - test was used to analyse the difference between the mean mortality in the Metarrhizium treatments and controls.

## 9.4 RESULTS

### 9.4.1 Bait Dosage Rate and Mortality

The relationship between dosage rate and porina mortality is shown in Figure 12 . Porina mortality peaked at a concentration of 0.4% ai/g dwt wheat, equivalent to using 0.13 kg ai/ha of insecticide. The post peak reduction in mortality indicates that baits with high insecticide rates were not being taken by porina.

### 9.4.2 Bait density and mortality

The relationship between bait density and porina mortality is shown in Figure 13. The baits were treated at 0.2 kg ai/ha, which was just above the optimal rate (Figure 12 ). Mortality remained relatively constant between 1 chip/6.25 $cm^2$ and 1 chip/12.5 $cm^2$. The optional bait density would be approximately 1 chip/12.5 $cm^2$.

### 9.4.3 Treatment and mortality relationships

Porina mortalities due to the different treatments are shown in Table 22. All treatments were significantly different ($P < 0.05$) from the controls.

TABLE 22: Porina mortalities resulting from various bait and spray treatments (after 10 days).

| Treatment | | Application Rate | % Mortality | Mean porina number per plot (± SE 95%) |
|---|---|---|---|---|
| Spray: | . Fenitrothion | 0.9 kg ai/ha | 88.4 | 5.8 ± 1.7 |
| Baits: | . Fenitrothion | (1)* | 73.7 | 5.1 ± 1.8 |
| | | (2)** | 70.8 | 4.8 ± 2.1 |
| | . Fenitrothion & Metaldehyde | (1) | 83.7 | 4.6 ± 1.9 |
| | | (2) | 76.5 | 4.3 ± 1.5 |
| | . Actellic | (1) | 84.6 | 5.3 ± 1.4 |
| | | (2) | 65.7 | 5.3 ± 1.9 |
| | . Vydate | (1) | 53.0 | 4.8 ± 2.1 |
| | | (2) | 59.9 | 4.7 ± 2.1 |
| | . Lindane | (1) | 54.9 | 4.6 ± 1.7 |
| | | (2) | 25.2 | 5.8 ± 2.0 |
| | . Sawdust | (1) | 34.1 | 5.4 ± 1.7 |
| | . Untreated (control) | (1) | 13.5 | 6.2 ± 1.5 |
| Nil: | . - (control) | - | 15.1 | 4.4 ± 1.6 |
| | LSD (5%) - 28.3 | | | |

* (1) 1 chip/6.25 $cm^2$
** (2) 1 chip/25 $cm^2$

Significant differences ($P < 0.05$) between mortalities at high and low insecticidal treatments are shown in Figures 23(a) and 23(b) by a (X) and non-significance is by the letters NS.

TABLE 23 : Significant differences ($P < 0.05$) between porina mortalities gained from different treatments.

| Treatment* | (a) At 1 chip/6.25 cm$^2$ | | | | | | (b) At 1 chip/25cm$^2$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | F | F&A | A | Vy | L | S | F | F&A | A | Vy |
| SD | X | X | X | X | NS | NS | | | | | |
| L | X | NS | X | X | NS | | X | X | X | X | X |
| Vy | X | NS | X | X | | | X | NS | NS | NS | |
| Act. | NS | NS | NS | | | | NS | NS | NS | | |
| F & A | NS | NS | | | | | NS | NS | | | |
| F | NS | | | | | | NS | | | | |

The column headings S, F, F&A, A, Vy and L are treatments.

*Key to treatments :

| Carrier | | Treatment (Abbreviation) |
|---|---|---|
| Sawdust Bait | . | Fenitrothion (S D) |
| Wheat Bait | . | Lindane (L) |
| | . | Vydate (Vy) |
| | . | Actellic (Act.) |
| | . | Fenitrothion & Metaldehyde (F & A) |
| | . | Fenitrothion (F) |
| Spray | . | Fenitrothion (S) |

Of the bait treatments actellic gave the greatest mortality at the highest rate, but at the lower rate dropped below that of Fenitrothion. The addition of metaldehyde to fenitrothion treated baits gave a slight increase in mortality at both rates indicating that slugs may be responsible for some removal of baits. Vydate and lindane gave low mortalities at both rates. Sawdust even though it is not a food source did give a significant but low mortality, perhaps because porina came into accidental contact with the treated particles on the surface.

Metarrhizium treatments gave a slightly lower mortality, although this was not significant ($P < 0.05$), from that of Metarrhizium plus fenitrothion, while (Table 23) both treatments were significantly different ($P < 0.05$) from the control.

9.4.4 Porina mortality and fungal treatments

The results are shown in Table 24.

TABLE 24: The mortality of porina in relation to different treatments of baits with Metarrhizium

| Treatment | % Mortality | Mean porina number per plot |
|---|---|---|
| Metarrhizium | 43.8 | 5.3 |
| Metarrhizium & Fenitrothion | 53.6 | 5.1 |
| Control | 17.4 | 4.3 |

Metarrhizium Development in Live Larvae

Live porina from fungal treated plots were placed in clean petri dishes at 20°C, and checked after 1, 2 and 3 weeks. 43% of these developed Metarrhizium bloom, and healthy larvae from insecticidally treated plots showed 5% development.

9.4.5 Baits removed per treatment

The percentage of dyed baits removed from four replicates of varying insecticidal treatments, and all the Metarrhizium and sawdust replicates is shown in Table 25 .

TABLE 25: Percentage removal of baits from varying treatment plots (after 10 days)

| Treatment | Rate | % Removal |
|---|---|---|
| Fenitrothion | (1) | 40.3 |
| | (2) | 38.0 |
| Fenitrothion & Metaldehyde | (1) | 33.3 |
| | (2) | 49.0 |
| Actellic | (1) | 53.0 |
| | (2) | 67.7 |
| Vydate | (1) | 44.0 |
| | (2) | 91.3 |
| Lindane | (1) | 63.3 |
| | (4) | 71.3 |
| Sawdust | (1) | 37.5 |
| Metarrhizium | (1) | 54.1 |
| Nil (controls) | (1) | 96.8 |

The results show an inverse relationship between the percentage mortality (Table 22 ) and percentage bait removal of different treatments. Where bait removal is low, mortality is high and vice versa.

9.4.6 Live caterpillar weights

The average weight of live caterpillars between the control and combined treated plots were not significantly different ($P < 0.05$).

9.4.7 Cover readings

Cover readings were taken from each plot in the treatment and mortality trial (Table 20). These are shown in summary in the Appendix. Overall average foliage cover was 89.7% and bare ground accounted for the other 10.3% in the plots. 93.5% of the cover was clover or ryegrass, and the remaining 6.5% was weeds. 75.7% of the weeds were flatweeds (e.g. Catsear (Hypochaeris radicata L.), hawksbeard (Crepis capillaris (L) Wallr.), dandelion (Taraxacum officinale, Weber) and daisy (Bellis perennis L.).

Affect of treatments on slugs and earthworms

The average number of dead slugs and earthworms on the surface of each treatment plot of the main trial, was very small. (Table 26). Trends indicated that all insecticides were mildly toxic to slugs, and Metaldehyde slightly more so. Vydate was the only toxic insecticide to earthworms.

TABLE 26: Dead slugs and earthworms on treated and untreated plots (after 10 days).

| Treatment | | | Rate | Mean number dead per plot | |
|---|---|---|---|---|---|
| | | | | Slugs | Earthworms |
| Spray: | . | Fenitrothion | 0.9 kg ai/ha | 0.1 | 0 |
| Bait: | . | Fenitrothion | (1) * | 0.9 | 0.3 |
| | | | (2) ** | 0.6 | 0.3 |
| | . | Fenitrothion & | (1) | 0.6 | 0.4 |
| | | Metaldehyde | (2) | 1.3 | 0.1 |
| | . | Actellic | (1) | 0.3 | 0.3 |
| | . | Vydate | (2) | 0.3 | 0.3 |
| | | | (1) | 0.4 | 2.1 |
| | . | Untreated (control) | (2) | 0.6 | 1.1 |
| | | | (1) | 0 | 0 |
| Nil: | . | - (control) | - | 0 | 0.3 |

* (1) 0.13 Kg/ha (1 chip 6.25 $cm^2$)

** (2) 0.03 Kg/ha (1 chip/25 $cm^2$)

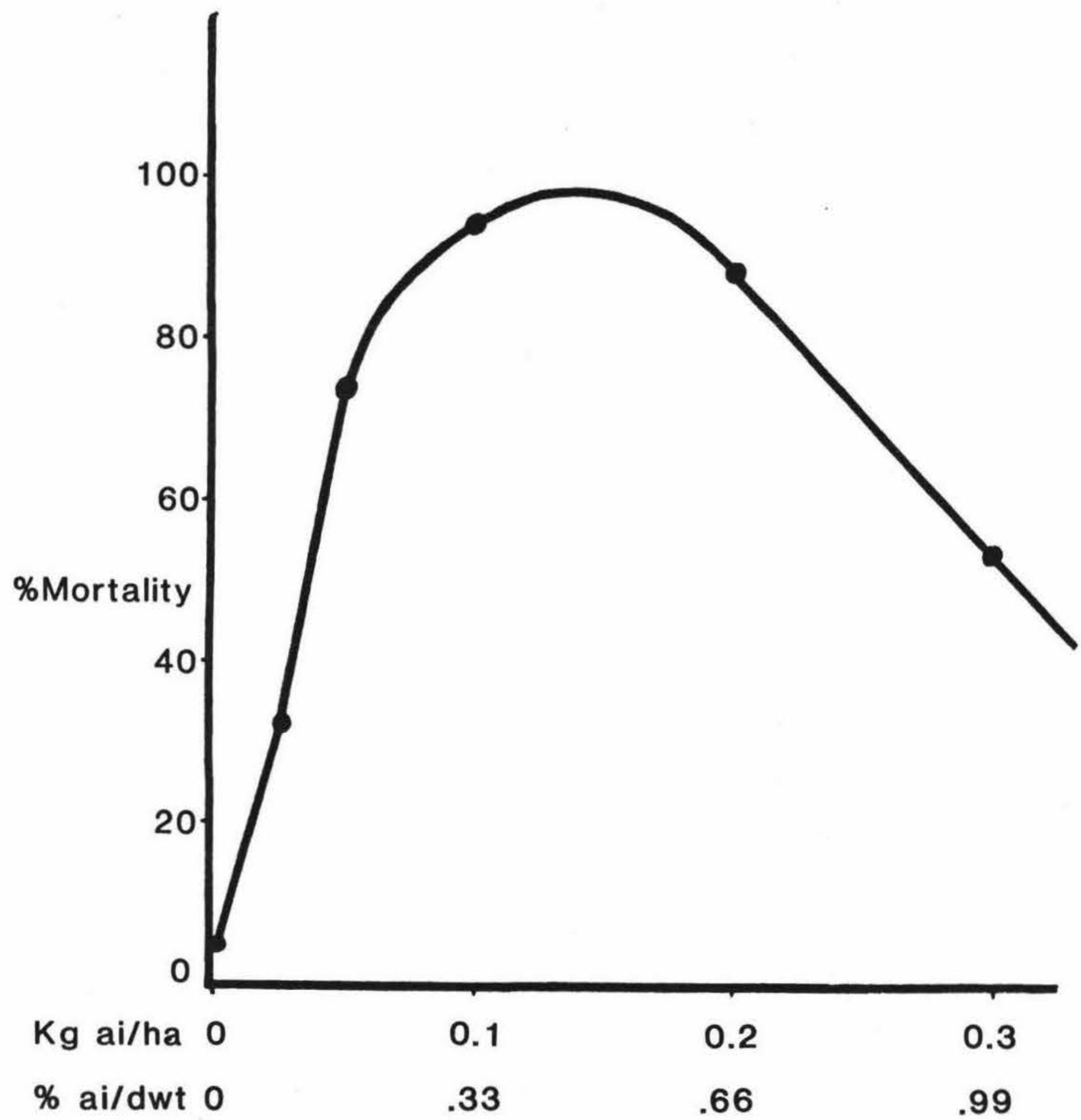


Figure 12: The relationship between porina larval mortality and the insecticide rate (Kg ai/ha) assuming a bait rate of 1 chip/6.25 $cm^2$, or dosage (% ai/d.wt), of wheat baits (No.1) applied in the field.

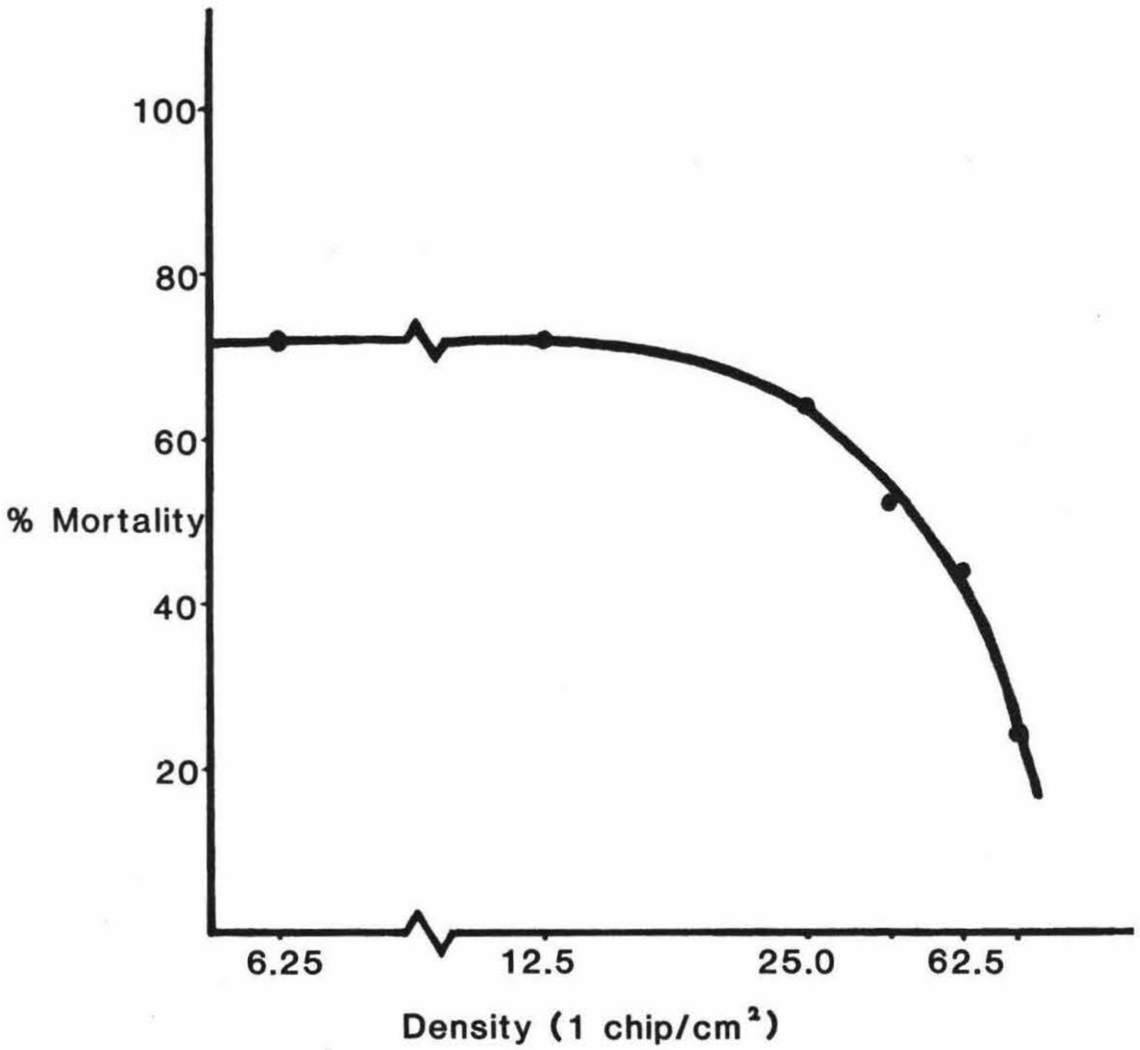


Figure 13 : The relationship between porina larval mortality and the treated wheat bait (No.1) density, applied in the field (assuming a fenitrothion rate of 0.2 Kg ai/ha).

# CHAPTER TEN

## PERSISTENCE OF BAITS AND SPRAY APPLICATIONS IN THE FIELD

### 10.1 INTRODUCTION

The success of the use of any type of toxic bait for the control of a pest is dependent upon the ability of the non-toxic bait component to carry enough lethal substance for a period enabling the pest to come into contact with it and subsequently die (Peregrine 1973). This is extremely important with respect to porina baiting, since it is economically necessary to decrease the insecticide dosage per hectare to less than the equivalent for spray applications. Therefore the success of a chip wheat bait is related to the length of period the lethal dosage rate is carried by the carrier in the field. The two main factors involved in determining this are:

1. The ability of the insecticide to remain on the bait.
2. The ability of the bait to remain acceptable to the caterpillar.

In this trial both factors have been assessed by removing treated and untreated baits and foliage from the field after specific time periods, and screening these food sources for their effects on healthy porina.

Two insecticides were used on the baits, fenitrothion and actellic and the former was used for the spray application. On pastures fenitrothion has a withholding period of 14 days. Actellic, being used mainly as a horticultural insecticide, has a withholding period of 28 days on fruit. Therefore it could be assumed that both chemicals are only moderately persistent on 'crops'.

Fenitrothion has been used since 1967 in the place of DDT for operational control of Lepidopterous defoliators in Canadian forests (Moody et. al. 1977). Since very large amounts of this chemical are used, the fate of the pesticide after spraying has received special attention. Reports indicate that 50% of the initial dose is lost by foliage within four days and 70-80% within two weeks of application to pine forests. However, 10% persisted for at least 10 months, which initiated the hypothesis that the waxes and oils in pine needles were 'micro-sinks' for the accumulation of the chemical (McNeil et. al. 1979, Moody et. al. 1977). The rapid disappearance of fenitrothion from corn (Zea mays) and bermudagrass (Cynodon dactylon) has also been reported (Leuck and Bowman 1969). Here, the decrease of the parent chemical sprayed on bermudagrass dropped approximately 100 parts per million (ppm) to 50 ppm over less than four days, to 5 ppm after eight days and to 0.05 ppm after 28 days. These workers and later Moody et. al. (1977) also substantiated the hypothesis that fenitrothion dissipation is largely the result of volatisation, and not some form of biodegradation. Therefore, it would be reasonable to assume that fenitrothion would persist longer in the field if soaked into a wheat chip, than if sprayed on foliage, and that oil would act as a waterproofing and sticking agent for the chemical (Martin 1980). Further it is tentatively postulated that the oil may, in this manner, act as a 'micro-sink' similar to the waxes and oils in pine needles. Actellic, because of its closely related chemical structure and properties to fenitrothion, may also fulfil the requirements for these phenomena.

## 10.2 EXPERIMENTAL DESIGN

Five ¼ $m^2$ plots were selected from closely grazed, porina free pasture. Three of these were sprinkled with 30 grams of one of three, presoaked bait treatments; fenitrothion and vegetable oil, actellic and vegetable oil, and vegetable oil by itself. A small 'Cambrian' sprayer was used to apply fenitrothion spray to another plot. The last plot was not treated. All insecticide and oil concentrations are outlined on page 8 and are those used in the Waikanae field trials.

## 10.3 SPECIAL METHODS

Treatment plots were assessed for the presence of lethal doses of insecticide after 0, 2, 4, 10 and 24 days after application. In the bait treated plots, at each sample time except 0 days approximately 200 chips were removed with forceps. At 0 days, wheat samples were taken before application. With the sprayed and untreated plots, samples of 5 averagely, but equal, sized clover leaves were removed after the time periods. Twenty of these baits or five leaves were then placed in individual petri dishes containing a healthy porina, making up ten porina for each treatment. An extra ten porina were fed individually with 20 pre-oiled, fresh chipped wheat baits. The porina, averaging 0.4 grams, were collected from the field (Hauorongo) and stored by the usual method at 7°C, until use.

Each of the sets of ten porina were placed at 10°C in darkness, and the health of the caterpillars assessed after one day and four days. A large percentage of insecticidally treated individuals, throughout these studies in the laboratory, and in the field, were noted for being almost dead but still retaining sporadic body movement for a number of days. Therefore since this phase is evident porina within it were classed as dead. A visual assessment of the amount of food consumed by each caterpillar was also recorded after one day.

Climatic observations were recorded from a local meteorological station's report.

## 10.4 RESULTS

### 10.4.1 Percentage mortality after four days

The data are given in Table 27. Porina fed on freshly sprayed clover leaves, and baits freshly treated with fenitrothion or actellic gave 100% mortality. The spray treatment dropped to 80% after four days, 40% after 10 days, and after 24 days it was nil. The point at which zero mortality as reached would however most certainly be lower than this (Fig. 11). Fenitrothion baits gave 100% up to 24 days after treatment, and actellic baits gave 90% at all points except 24 days, at which it was 100%. After 24 days baits were so degraded that testing was abandoned.

The three control mortalities are also shown in Fig 14 No more than one caterpillar died in any of these, and all that died developed Metarrhizium anisopliae fungus. Therefore the mortalities are meaned on the graph.

### 10.4.2 Percentage mortality after one day

Mortalities after one day's exposure compared to four days is shown in Table 27 Most deaths occurred within the first day, indicating that both insecticides are fast acting. After four days it was evident that if further mortality resulted, insecticide effect could not be easily shown to be responsible.

TABLE27: Porina mortality (%) when fed field exposed treated and untreated food sources.

| TREATMENT | | | | CONTROLS | | | |
|---|---|---|---|---|---|---|---|
| Treatment | Field exposure | % Mortality | | Treatment | Field exposure | % Mortality | |
| | | 1 day | 4 days | | | 1 day | 4days |
| BAITS | | | | BAITS | | | |
| Fenitrothion | 0 | 100 | 100 | Oil only | 0 | 0 | 10 |
| | 2 | 100 | 100 | | 2 | 0 | 0 |
| | 4 | 90 | 100 | | 4 | 10 | 10 |
| | 10 | 80 | 100 | | 10 | 0 | 0 |
| | 24 | 80 | 100 | | 24 | 0 | 10 |
| Actellic | 0 | 90 | 100 | Oil only fresh* | 0(0) | 0 | 10 |
| | 2 | 90 | 90 | | 0(2) | 10 | 10 |
| | 4 | 90 | 90 | | 0(4) | 10 | 10 |
| | 10 | 70 | 90 | | 0(10) | 10 | 10 |
| | 24 | 80 | 100 | | 0(24) | 0 | 0 |
| SPRAY | | | | NIL | | | |
| Fenitrothion | 0 | 100 | 100 | | 0 | 0 | 0 |
| | 2 | 100 | 100 | | 2 | 0 | 0 |
| | 4 | 80 | 80 | | 4 | 10 | 10 |
| | 10 | 30 | 40 | | 10 | 0 | 10 |
| | 24 | 0 | 0 | | 24 | 0 | 0 |

* number inside bracket corresponds to the time treated foods were exposed.

### 10 .4.3 Food consumed after one day

This assessment was taken after all except 24 days, by counting the number of bait fragments and the amount of clover leaf that remained. These are expressed as percentages of total amount originally given (Table 28). The trends showed that the amount of treated bait consumed was less than the untreated, which is accounted for by the death of the porina. Untreated baits were chosen less if fresh than if worn, which may be due to a preference for an increased moisture level in the latter. However these latter differences were not significant (p 0.05).

TABLE 28: Percentage (%) of total number of baits and area of clover offered, consumed (after 1 day at 10°C).

| Treatments | | | Controls | | |
|---|---|---|---|---|---|
| Treatment | Field exposure (days) | % Food left ± SE | Treatment | Field exposure (days) | % Food left ± SE |
| BAITS | | | BAITS | | |
| Fenitrothion | 0 | 94 ± 4.6 | Oil only | 0 | 67 ± 21.5 |
| | 2 | 91 ± 6.3 | | 2 | 48 ± 19.0 |
| | 4 | 98 ± 2.5 | | 4 | 44 ± 21.8 |
| | 10 | 97 ± 3.2 | | 10 | 28 ± 21.1 |
| Actellic | 0 | 93 ± 4.6 | Oil only, fresh* | 0 | 67 ± 21.5 |
| | 2 | 86 ±12.5 | | 0(2) | 61 ± 21.1 |
| | 4 | 95 ± 3.9 | | 0(4) | 76 ± 27.5 |
| | 10 | 97 ± 5.4 | | 0(10) | 56 ± 17.2 |
| SPRAY | | | NIL | | |
| Fenitrothion | 0 | 32 ± 7.2 | | 0 | 56 ± 25.8 |
| | 2 | 54 ± 11.4 | | 2 | 42 ± 28.6 |
| | 4 | 42 ± 15.7 | | 4 | 74 ± 38.6 |
| | 10 | 52 ± 27.2 | | 10 | 45 ± 38.6 |

* number inside bracket corresponds to the time treated foods were exposed.

### 10.4.4 Climate

The average daily rainfall between the five field exposure periods in ascending order of length were 0.17 mm, 0.6 mm, 2.8 mm and 4.3 mm. On the 20th and 21st day 43 mm of rain fell. Since these figures are typical of the rainfall in this area for the time of year, it was concluded that the comparison of persistence of bait and spray applications was not biased by an abnormal lack of precipitation over the trial period. Other climate factors were noted, but did not show abnormal trends., and are shown in Appendix five.

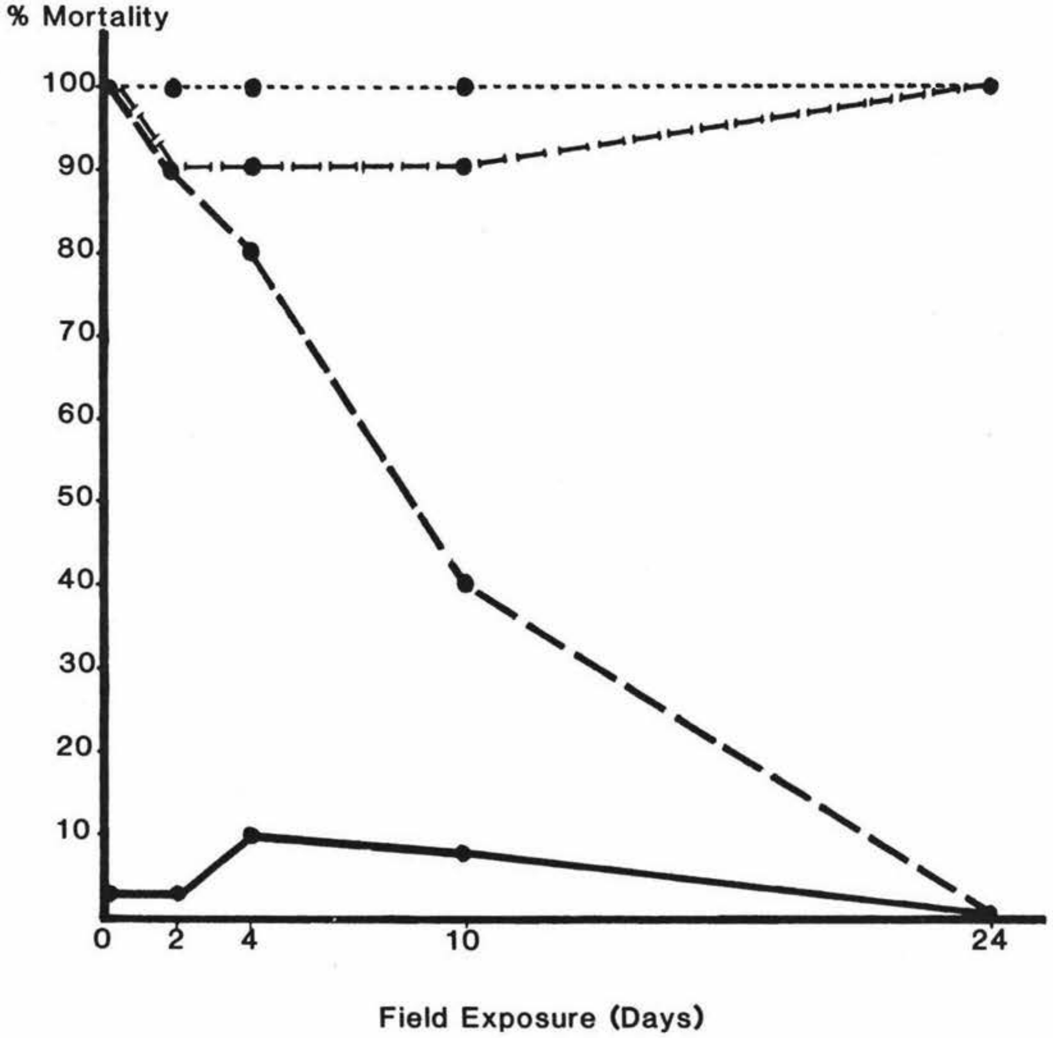


Figure 14: The relationship between the mortality of porina larvae when fed fenitrothion (-----)., and actellic (⊢ ⊢ ⊢) treated wheat baits (size No.1) fenitrothion sprayed leaves (— —) and untreated wheat baits (———), that had been exposed for varying days in the field.

# CHAPTER ELEVEN

## WAIKANAE LARGE PLOT FIELD EXPERIMENTS

### 11.1 INTRODUCTION

To evaluate the use of chipped wheat baits on a larger scale, trials were conducted in hill country inland from Waikanae (see page 15 ). This area is renowned for consistently heavy porina infestations. Two flight peaks occur each year, a small peak in early December, and a second, larger peak in early March. These fluctuations are not directly related to the flight peaks of the two major species, Wiseana cervinata and W. umbraculata, present. (Carpenter and Wyeth 1980). Visible damage is not generally seen until early spring. The area is predominately sheep grazed and is typical of the lower North Island hill country. Much of the land is only partially cleared, the soils are friable, the terrain steep and the weather is extremely changeable. Management procedures to counter porina infestations centre on areas, oversowing. Control procedures, generally consisting of aerial applications of fenitrothion, either as a spray or in a prill formulation, are either carried out spasmodically or more often, not at all. Cost (page 108 ) is the limiting factor here in porina control, and therefore the use of lower cost methods is attractive.

Findings from previous chapters enable these large trials to be refined within workable and meaningful limits. These were:

(1) The size of bait was limited to size No. 1. Previous work has shown that acceptance of chipped bait is not significantly affected by the size of the chip (page 23 ). Size No. 1 is considered also to be the smallest a chip can be to retain ballistic properties enabling even application, insecticide retention properties enabling a lethal dose of insecticide to be carried, and weathering properties enabling the bait to withstand decay and disintegration for an extended period.

(2) The use of only two insecticides, fenitrothion and actellic, as both had shown promise in the field (page 63 ). Later two more insecticides, lindane and methiocarb, were assessed for future reference. Since the use of the first two insecticides validated previous work, it was believed that both lindane and methiocarb may refine the future use of chipped wheat baits; lindane because of its low cost and persistence, and methiocarb because of its insecticidal and molluscicidal properties. Methiocarb in this respect has a decided advantage over metaldehyde which was used in the previous trials since it is a molluscicide only.

(3) The assessment at only two baiting rates, and at one bait insecticide loading. This enabled further evaluation, to be made on the optimal baiting rate, retaining what is considered the optimal bait insecticide loading (page 62) constraint. As a precaution one treatment of twice the fenitrothion insecticide dosage and lowest bait density was included in a later trial.

(4) The use of, at first, wheat infected with Metarrhizium plus a low dosage of fenitrothion. Metarrhizium was tried again alone later in these trials since it was found that the use of an insecticide may be unnecessary in this area to gain effective porina mortality.

Within these limits, the large plot field trials then were conducted in the time period restricted by the lifecycle of the insect.

These trials were carried out in October, November and December 1980. The first sampling commenced on 19 October, and the last concluded on 22 December. Work on the four major trial blocks was completed on 4 December. A co-operative Metarrhizium trial, not reported on here, was completed early in the New Year of 1981, when pupation of the larvae was well under way and flights were beginning.

## 11.2 EXPERIMENTAL DESIGN

Field plots were selected visually by locating areas with varying aspects, and moderate to high populations of porina. Fourteen centimeter spade-square pre-samples were dug around these areas enabling trial sites to be marked within uniform infestations. This is not as accurate as may be suggested, since porina populations are often sporadic in numbers, even within small areas. However the procedure does limit the chance of having large population fluctuations within the experimental site. Plots were then measured and marked with white pegs and, the location, aspect, and mean cover, (100 points per plot) were recorded.

The original design consisted of seven 2 m x 10 m adjacent treatment plots, marked lengthways down the prevailing slope. Later, extra blocks used the same pattern, but had less treatment plots. The treatments in the original blocks (Table 29) were allocated by random numbers, and replicated four times. The two later blocks were not replicated (Table 30).

TABLE 29: Original treatments in the large plot trials (replicated 4 times)

| Treatment | Type of insecticide | Insecticide dosage | Application rate |
|---|---|---|---|
| Control | - | - | |
| Insecticide | | | |
| - Spray | Fenitrothion only | 0.9 kg ai/ha | 1200 litres/ha |
| - Baits | Fenitrothion, Actellic | 0.13 kg ai/ha | 1 chip/6.25 $cm^2$ |
| | Fenitrothion, Actellic | 0.03 kg ai/ha | 1 chip/25 $cm^2$ |
| Insecticide + Fungus | | | |
| - Baits | Metarrhizium anisopliae + | - | |
| | Fenitrothion | 0.01 kg ai/ha | 1 chip/6.25 $cm^2$ |

TABLE 30: Later treatments in the large plot trials (not replicated)

| Treatment | Type of Insecticide | Insecticiee dosage | Application rate |
|---|---|---|---|
| Control | - | - | - |
| Insecticide | | | |
| - Spray | Fenitrothion | 0.9 kg ai/ha | 1200 litres/ha |
| - Baits | Lindane, Methiocarb | 0.13 kg ai/ha | 1 chip/6.25 $cm^2$ |
| | Lindane, Methiocarb | 0.03 kg ai/ha | 1 chip/25 $cm^2$ |
| | Fenitrothion | 0.06 kg ai/ha | 1 chip/25 $cm^2$ |
| Fungus | | | |
| - Baits | *Metarrhizium anisopliae* | - | (1 chip/6.25 $cm^2$) |

Four soil samples were taken from each treatment after three or four time periods. These were cut 0.4 m square (0.16 $m^2$) and dug to a depth of approximately 30 cm, or to the depth of the topsoil, whichever came sooner. Porina were never found below this topsoil layer. The samples were then hand sorted and the number of alive and dead porina recorded. *Metarrhizium*-infected dead larvae were also noted. Each 0.16 $m^2$ sample was taken from one of four squares allocated at random within each sub-site (Fig.15 ). Samples were taken after 0 days (before treatment), 10 days and 30 days. Block two had a fourth sample taken after 20 days. Therefore at all except one site, the treatments had twelve 0.16 $m^2$ samples taken from them; three from each of four interior sub-sites, leaving one 0.16 $m^2$ from each of these sub-sites not dug. The reason for this sampling procedure was to avoid large errors due to patchy porina populations. The four very close areas to be dug within the sub-sites would give the least amount of variability in the live larvae at the beginning of the trials.

## 11.3 SPECIAL METHODS

Comparing these large plot trials and the earlier small plot trials, there were some major changes in special methology, due to the size difference. These were:

(1) Plots were pegged rather than bordered by fibrolite sheets, and were not covered.

(2) The treatments were sub-sampled and these samples were 0.16 $m^2$ (0.4 m square) rather than 0.2 $m^2$ (0.45 m. square).

(3) The treatments were pre-sampled as well as having a control that was not treated.

(4) No counts of baits removed were taken.

(5) Baits were sprinkled on the surface through a perforated plastic 'TVL specimen container'. To enable consistency of spread, each treatment was split into four, and the correct amount of bait applied to each section.

(6) Instead of a small 'Cambrian' sprayer being used for the spray application, a back mounted propane sprayer with a one metre boom was used. Plots were covered by one, timed application of spray, up one side of the plot and down the other.

The analysis of percentage mortalities, was assessed, for each treatment, from the mean of each sample from the four sub-sites. An analysis of variance was carried out to test for significance (p 0.05) between treatments, and this was shown as a percentage mortality. The presence of significant differences ($p < 0.05$) between the sites, sample replicates and controls were also analysed.

## 11.4. RESULTS

### 11.4.1 Overall trends in initial treatments

Percentage mortalities can be seen in Table 3.1. Overall a very high mortality (96.8%) was achieved with fenitrothion spray. This is most probably due to the care taken to get full coverage, and to have ideal conditions for spraying. Fenitrothion and actellic treated chipped wheat baits performed very similarly, with the lower baiting rates affecting the mortality by approximately 10% after 30 days. Metarrhizium plus a low dosage of fenitrothion was surprising in its large mortality after 30 days.

### 11.4.2 Trends between mortality and time

Between 10 and 30 days mortalities in the low bait treatments and the Metarrhizium treatments were significantly increased. This is probably because of the relationship between bait availability and foraging behaviour of the caterpillar, in the low baiting rates, and also, in the fungal treatments, to the time that Metarrhizium takes to develop within the insect. This is approximately 14 days (G.M. Latch *pers. comm.*) The high bait rates, and the spray invariably have a major effect within the first 10 days, due to the availability of the poisoned food source. A significant increase from the initial high knock-down does not occur since the number of larvae left is very low in the case of wheat baits and spray. In the case of the spray the insecticide becomes ineffective after an extended period, also.

### 11.4.3 Trends between mortality after three time periods and treatments

In trial No.2 samples were taken after 10 days, 20 days and 30 days, and the mortalities are shown in Table 32. This trial was complicated by a significant loss in the control population between the 10 and 20 day interval, which did not occur in any of the other trials. This mortality which was not significantly different after 10 days, was significantly different from controls after 30 days. The major point gained from taking a third sample was that increases in porina mortality at low baiting rates was relatively constant. The same was true for Metarrhizium mortality.

### 11.4.4 The use of lindane and Metarrhizium only

Mortality with lindane at high and low baiting rates over 10 and 30 days were similar (Table 33). The control was moderate, and did not increase significantly after 10 days, as expected. This result with lindane may be due to the emulsified powder/oil solution not allowing penetration of the insecticide into the grain, or that the lethal dosage rate dropped sufficiently after 10 days, due to weathering, allowing porina to consume treated baits safely.

TABLE 31 : Percentage mortality in the major trials, after 10 and 30 days

| Treatment XX | % Mortality X | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Site 1 | | Site 2 | | Site 3 | | Site 4 | | Mean | |
| | 10 | 30 | 10 | 30 | 10 | 30 | 10 | 30 | 10 | 30 |
| (1) | 87.3* | 90.5 | 95.6* | 97.8 | 98.8* | 98.8 | 97.4* | 100 | 94.8* | 96.8 |
| (2) | 76.9* | 76.9 | 80.4* | 91.3 | 84.6* | 92.3 | 91.1* | 96.4 | 83.3* | 89.2 |
| (3) | 29.2 | 58.3** | 53.3* | 82.2** | 66.7 | 53.7 | 62.5* | 70.8 | 52.9* | 66.3** |
| (4) | 74.0* | 83.6 | 63.6* | 88.6** | 83.9* | 87.5 | 66.0* | 74.0 | 71.8* | 83.4 |
| (5) | 30.9* | 44.1 | 45.9* | 82.8** | 61.2* | 88.1 | 55.2* | 65.7 | 48.3* | 70.2** |
| (6) | 16.2 | 47.1** | 25.5 | 80.9** | 27.9* | 85.2** | 32.7* | 90.4** | 25.6* | 75.9** |
| (7) | 13.8 | 10.3 | 20.0 | 45.8 | 0 | 16.7 | 7.9 | 27.4 | 10.4 | 25.1 |

X A star (*) after the mortality denotes significance ($p < 0.05$) of 10 day mortalities from the controls. Two stars (**) denote significance (p 0.05) of 30 day mortalities from the 10 day mortalities.

XX Treatments were
(1) Fenitrothion spray
(2) Fenitrothion treated bait at 1 chip/6.25 $cm^2$
(3) Fenitrothion treated bait at 1 chip/25 $cm^2$
(4) Actellic treated bait at 1 chip/6.25 $cm^2$
(5) Actellic treated bait at 1 chip/25 $cm^2$
(6) *Metarrhizium* plus Fenitrothion at 1 chip/6.25 $cm^2$
(7) Control

TABLE 32 : Percentage mortalities at site No.2 after 10 days, 20 and 30 days

| Treatment | % Mortality X | | |
|---|---|---|---|
| | 10 days | 20 days | 30 days |
| (1) | 95.6* | 91.1 | 97.8 |
| (2) | 80.4* | 84.7 | 91.3 |
| (3) | 53.3* | 73.3 | 82.2** |
| (4) | 63.6* | 79.5 | 88.6** |
| (5) | 45.9* | 70.5 | 82.8** |
| (6) | 25.5 | 30.2 | 80.9** |
| (7) | 20.0 | 42.7 | 45.8** |

X - A single star denotes a significant ($p < 0.05$) increase of 10 day mortalities over the controls. A double star denotes a significant ($p < 0.05$) increase over the 10 day period.

TABLE 33: Percentage mortalities at the first additional site, No. 5 after 10 days and 30 days

| Treatment | % Mortality 10 days | 30 days |
|---|---|---|
| Lindane bait at 1 chip/6.25 $cm^2$ | 58.1* | 58.1 |
| Lindane bait at 1 chip/25 $cm^2$ | 52.2* | 49.3 |
| Metarrhizium alone at 1 chip/6.25 $cm^2$ | 25.0 | 53.0** |

* A star denotes significant ($p < 0.05$) increase of the 10 day mortalities over the controls.

** Denotes a significant increase over the 10 day interval.

Metarrhizium, by itself, showed a lower mortality than when combined with an insecticide. However as expected, a significant increase in mortality was seen between the 10 days and 30 day interval.

### 11.4.5 The use of methiocarb baits, and fenitrothion baits at a high dosage

Methiocarb performed extremely well in this unreplicated trial (Table 34). After 10 days treatments were significantly ($p < 0.05$) different from the controls. A significant increase in mortality between 10 days and 30 days was seen in both the high and low rate of baiting, however, again, the low rate was most pronounced in its change.

The high fenitrothion bait dosage treatment gained slightly over the results from the first four trials (Table 31) with the same application rate, but lower insecticide dosage.

TABLE 34: Percentage mortalities at the second additional site, No. 6 after 10 days and 30 days

| Treatment | % Mortality 10 days | 30 days |
|---|---|---|
| Methiocarb at 1 chip/6.25 $cm^2$ | 84.6 * | 100.0 ** |
| Methiocarb at 1 chip/25 $cm^2$ | 39.6 * | 87.5** |
| Fenitrothion at 2 x insecticide loading at 1 chip/25 $cm^2$ | 82.7 * | 96.6 |

This rate performed as well as the high application rate and low dosage bait treatment in the earlier trials. The increase between 10 days and 30 days was not significant.

### 11.4.6 Differences in mean numbers of live porina between plots and sampling times

An analysis of variance on total live porina in samplings between treatments, plots and samples (replicates) for the 4 major sites was carried out. Significant differences (p 0.05) occurred between sites (Table 35) but did not occur between sampling plots within these sites. There were also no significant (p 0.05) differences between initial populations in each treatment, at each site. Overall mean porina numbers were 86 porina per $m^2$, ranging between 107 and 74 at different sites.

TABLE 35: Initial mean porina populations (per 0.16 $m^2$) at the trial sites.

| Plot Number | Mean porina population (/0.16 $cm^2$) |
|---|---|
| 1 | 17.1 |
| 2 | 11.9 |
| 3 | 15.3 |
| 4 | 13.4 |
| 5 | 15.3 |
| 6 | 12.9 |
| MSD (5%) - | 1.6 |

11.4.7 Cover readings

Cover readings from five of the six sites were recorded by taking 100 readings with a point analyser, uniformly over the area of each site. (Table36 ).

TABLE 36: Cover (%) recording from five treatment sites

| Class of cover | Site number | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| | 1 | 2 | 3 | 4 | 5 | Mean |
| Ryegrass | 85.3 | 69.1 | 64.8 | 92.0 | 68.0 | 75.8 |
| White clover | 38.9 | 11.7 | 5.5 | 48.0 | 24.0 | 25.6 |
| Flatweeds | 21.1 | 34.0 | 53.8 | 6.0 | 28.0 | 28.6 |
| Other weeds | 29.5 | 18.1 | 14.3 | 11.0 | 16.0 | 17.8 |
| Bare ground | 5.0 | 6.0 | 9.0 | 0 | 0 | 4.0 |

11.4.8 Aspects of trial sites

The general direction each site was exposed to and their mean slope down each site lengthways is shown in table 37.

TABLE 37: The direction exposed to and slope, of each trial site

| Site Number | Direction facing | Prevailing Slope |
| --- | --- | --- |
| 1 | West | 16° |
| 2 | North West | 21° |
| 3 | North | 6° |
| 4 | Nil (sheltered) | 8° |
| 5 | West | 5° |
| 6 | South East | 15° |

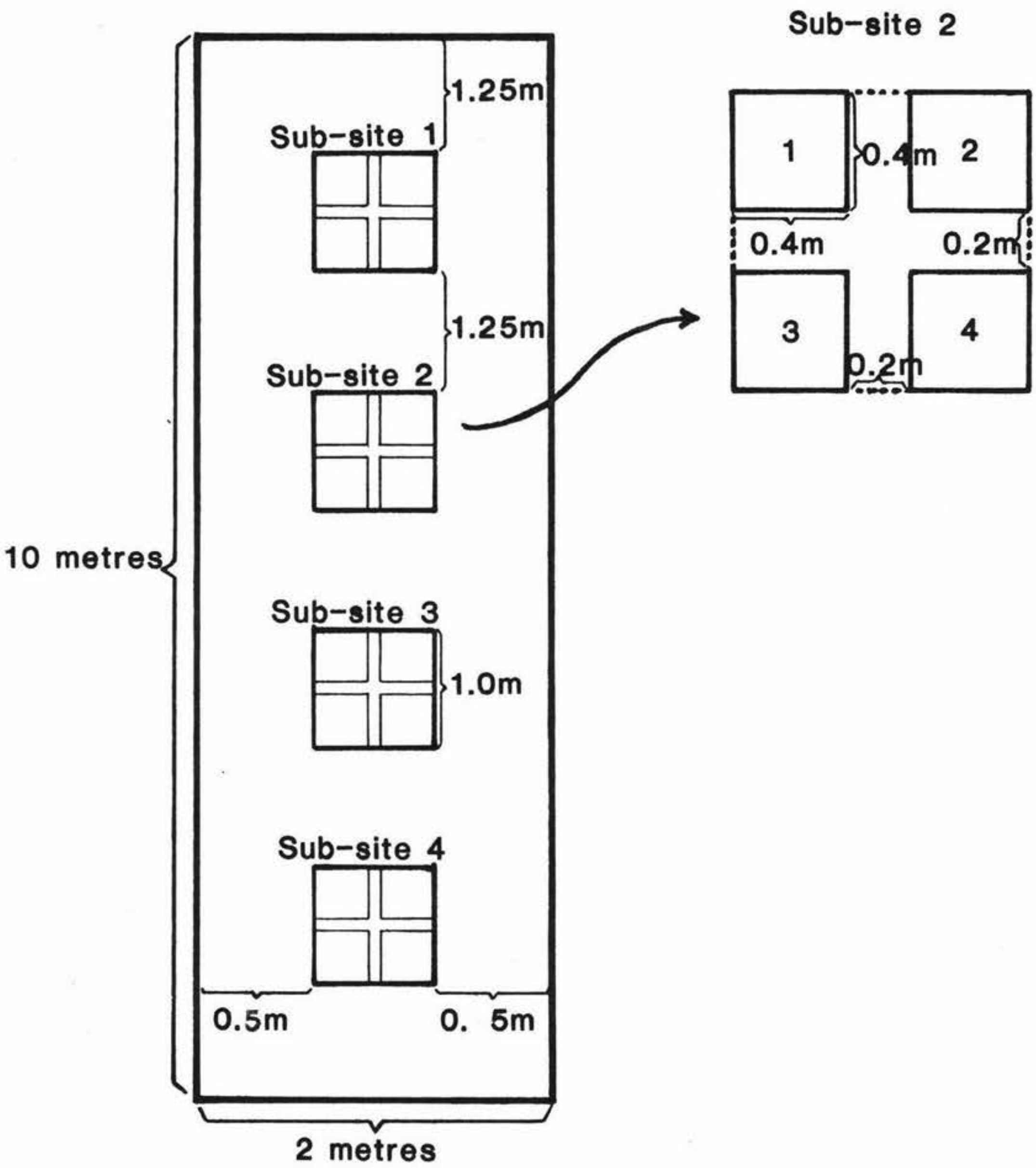


Figure 15: A diagram of the sampling design used in the large plot field experiments, for each treatment. Four samples; one from each subsite were taken over each time period.

# CHAPTER TWELVE

## DISCUSSION AND CONCLUSIONS OF FIELD TRIALS

### 12.1 HAUORONGO SMALL PLOT EXPERIMENTS:

Field application of chipped wheat baits treated with biocides lead to porina mortality. Bait treatments gave comparative but not as effective control of porina populations as the fenitrothion spray application. The effectiveness of the spray applications were probably enhanced by the small scale application technique used which gave much better spray cover than conventional methods. Actellic and fenitrothion were the most promising insecticides for incorporation onto wheat baits. Metaldehyde increased the mortality rate of fenitrothion bait treatment slightly, indicating that slugs may have stolen baits without a molluscicide.

The most efficient bait density was found by varying bait density and keeping the dosage rate of fenitrothion on each chip constant at 0.66 Kg ai/d wt. The optimal density was approximately 1 chip/12.5 $cm^2$. These results are substantiated from the main trial, since mortality was reduced between 1 chip/6.25 $cm^2$ and 1 chip/25 $cm^2$.

By varying fenitrothion dosage rates on baits and comparing their treatment mortalities, an optimal dosage rate was assessed (approximately 0.4% ai/ha). At high dosage rates, baits were not as effective, possibly because porina were repelled and a reduction in mortality resulted.

Bait disappearance and percentage mortality were inversely related in the bait treatments. This is the result of mortality being directly related to the toxicity, to porina, of the insecticide used.

The use of sawdust as a substitute for wheat was not successful, although the treatment did show a significant advantage over the controls.

Baits infected with <u>Metarrhizium</u> alone and combined with the low rate of fenitrothion were both only moderately successful in controlling porina. The continuation of these treatments at the next field site, was hoped to enlighten the possible reasons for these results.

12 .2 PERSISTENCE OF BAITS AND SPRAY APPLICATIONS IN THE FIELD:

Both fenitrothion and actellic treated baits were persistent for the length of life of the bait itself, and gave 100% mortality after 24 days, whereas fenitrothion spray had lost its toxicity after about 16 days. These results indicate that these chemicals persist on baits, with oil being a waterproofing and sticking agent (Martin 1980). The loss of fenitrothion from foliage is in accord with the results of others. (Leuck and Bowman 1969, Moody et. al. 1977).

The increase in consumption of field exposed untreated wheat bait, over unexposed wheat, may be due to its increased moisture level.

12.3 WAIKANAE FIELD EXPERIMENTS:

Applications of treated baits in these large plot field trials, gave significant porina mortality. Fenitrothion and actellic treated baits gave comparable but slightly lower results to spraying fenitrothion, however the spray was applied at a high water rate and under ideal conditions.

Between sampling after 10 days, and 30 days both bait treatments gave significant rises in control, at low bait densities. This is due to the availability of baits to each porina, since with extra time foraging porina have more chance to make contact with a wheat chip.

Metarrhizium infected baits with insecticide and without, gave relatively high control after 30 days, with the former being more effective.

Cover readings were not directly related to percent mortality at sites, but the difference in the composition of the cover was small. Flatweeds made up a prominent proportion of the foliage, due to the high infestation of porina present.

The direction exposed of each trial site, and their downhill slope were mixed. Any relationships between these and the treatment mortalities were not evident, and therefore pooling of results was acceptable.

## 12.4 GENERAL DISCUSSION AND CONCLUSIONS OF FIELD TRIALS.

In general the results obtained in field trials were similar, but some minor differences occurred. These were most evident in the level of control recorded in the lower bait rate of both fenitrothion and actellic. Initial mortalities at this rate, assessed after 10 days at Hauorongo were higher than those recorded at Waikanae. However after 30 days levels of control at both sites were similar. One reason for the slower knock-down, recorded at the former site, may be attributed to the lower night temperatures and rainfall experienced at Waikanae which would inhibit porina feeding. Trials at Hauorongo were covered with tents, which would shelter porina from both of the climatic variables. Comparable mortalities were recorded after 30 days, probably due to the fact that the extended time had allowed most porina at Waikanae to make contact with treated baits. Another reason may be that since populations at the later site were larger than at Hauorongo, the number of baits closely available to individual porina at Waikanae was markedly decreased by bait removal. This assumes that a small quantity of baits are removed from the surface by porina before death. Within 30 days surviving foraging porina had more chance to come into contact with baits, and therefore mortality increased.

In the past one of the main objections to the continued use of bran baits treated with inorganic insecticides (e.g. paris-green) was their relative ineffectiveness when applied to high porina populations. (Kelsey et. al. 1950) This resulted from the removal of large numbers of baits from the surface of the pastures permitted by the slow knock-down of these chemicals. However this was not the case in these studies, where the removal of baits treated with organophosphate insecticides was relatively low, indicating that these give a more rapid knock-down of porina.

The use of sawdust as a substitute for chipped wheat did not prove successful in the field trial at Hauorongo. This supports previous findings that inert carriers are not acceptable to foraging porina (Dumbleton & Dick 1942, Dumbleton et. al. 1948). From these studies it was obvious that although porina accepted all baits offered they had a slight preference for foods compared to inert materials (e.g. saw-dust and pith). Further research in this field may be instigated by economic considerations.

Wide differences in the cost effectiveness of baiting materials are known to exist for field crickets (Smith 1966, Blank 1980). Work herein indicates food preferences of porina are evident but are not as marked as those recorded for crickets. Further studies are needed to screen, in the laboratory, cheaper sources of baits for porina control than wheat, and then evaluate these in the field. The optimal size and persistent qualities of any substitute material for porina baits, is important to its efficiency. Wheat (size No. 1) was selected as a size which was relatively small, thus it has a reduced cost to larger baits, but still retains porina acceptance, ballistic properties, and persistence, (page 73 ) and unless the new material has identical physical properties and acceptance, these criteria for bait size would warrant re-evaluation.

The use of different biocides on baits for porina control also merits further investigation. Results using both an insecticide and molluscicide (fenitrothion and metaldehyde) treated bait at Hauorongo, and a combined moluscicide-insecticide (methiocarb) treated bait at Waikanae, indicated that protection of baits from slugs increases the effectiveness of porina control obtained. Methiocarb is a known bird repellent and molluscicide, and hence confers bird protection, as well as slug protection to baits applied for porina control. The use of this chemical against porina needs a fuller assessment than has been possible in these studies, to ascertain optimal dosages and cost. Since fenitrothion and actellic treated baits give high levels of control at about optimal baiting rates (page 62 ) the main reasons for evaluating other insecticides for bait treatment would be to increase the cost efficiency of bait formulations. As the cost of the insecticide is only a small fraction of the total formulation cost (Appendix SIX ) unless candidate biocides increase the spectrum of invertebrate pest control or protect baits from theft by non-target animals, advances in the cost-efficiency of porina control through this method are unlikely to be spectacular. However feeding studies to determine the acceptability of different insecticides applied at different dosages to baits merits further consideration, since these studies have shown that high insecticidal rates on baits can be repellent and therefore adversely affected porina control. The resistance of porina to some chemicals, e.g. synthetic pyrethroids (du Toit and Townsend 1978), also merits consideration when assessing new chemicals.

The use of baits as a carrier for the introduction of naturally occurring diseases appears promising. Metarrhizium infested baits in bothfield trials gave significant pest mortality. Higher death rates were recorded at Waikanae where cover was much reduced to that at Hauorongo, which would affect the acceptance of fungal infested baits, and the overall daily temperatures were higher affecting the development of the organism. Metarrhizium applied with rates of fenitrothion below that which gave detectable levels of control, (Figure 12 ) had slight although non-significant ($P < 0.05$) increases in control at Hauorongo and Waikanae over just Metarrhizium. In view of claims from Red China (Hsiu et. al. 1973)that low rates of BHC has a synergistic effect on Beauvera brassiana in control of the European Corn-borer (Ostrinia nubilalis (Hubner) ) further examination of porina control with Metarrhizium and sub-lethal dose of insecticides, is required. The relationship between temperature and the level of Metarrhizium control obtained is also in need of further study. The selection of more cool tolerant strains of this fungus, in order to expand the range of temperatures that this pathogen is effective against porina, warrants consideration as the results from Waikanae clearly demonstrate that it is an effective method of control under suitable environmental conditions.

Laboratory studies have shown that Metarrhizium infected baits are not as readily accepted by the pest as untreated baits and herbage. This did not seem to adversely affect the levels of control obtained at Waikanae and fungal infected baits were found in food caches in porina burrows here. This may be due to the advanced stage of pest damage on the trial sites, which increase the acceptance rate of Metarrhizium infested baits.

The substantial proportion (43%) of apparently healthy larvae collected from fungal treated plots after 30 days raises the question as to what the true mortality resulting from this treatment under field conditions was. It is the author's opinion that porina kept under stress conditions in the laboratory, which favour development of Metarrhizium, will be susceptible to the fungus. It is implied that the field collections of live porina which died in the laboratory and were found to be infected with the fungus, if left in the field may not have been killed by this disease. Hence the mortality assessed in the field, at Hauorongo (44%) after 30 days, may reflect the true effect of the fungus, more so than results corrected from laboratory observations on infection of live larvae after sampling.

It is clear from these and other studies (Latch 1965) that under low temperatures the mortality caused by Metarrhizium may be too low and/or slow to minimize economic losses in pasture. Hence the efficient use of this disease will have to take into account important variables influencing its rate of application and effectiveness.

## 12.5 COST ANALYSIS FROM FIELD TRIALS:

The cost effectiveness of traditional fenitrothion sprays in relation to a high and low bait density, at near optimal bait loading was assessed (Table 1) using results obtained in these studies, and cost estimates obtained from various sources (see Appendix SIX).

TABLE 38 : A comparison of spray and bait treatments.

| Treatment | Rate | % Mort. | Cost* |
|---|---|---|---|
| Control | - | 14.3 | - |
| Insecticide formulation - | | | |
| Spray - 0.8 kg ai/ha | | 88 | $46.00 |
| Bait - 0.13 kg ai/ha | | 81 | $19.10 |
| 1 chip/6.25 $cm^2$ | | | |
| 0.03 kg ai/ha | | 71 | $11.30 |
| 1 chip/25 $cm^2$) | | | |
| LSD (5%) | | | |

* including application costs

# CHAPTER THIRTEEN

## GENERAL DISCUSSIONS AND CONCLUSION

### 13.1 GENERAL DISCUSSIONS:

The intended use of chipped wheat baits for porina control is directed towards the extensively farmed pastoral hill country of the lower North Island (page 1). Its relevance to other areas of New Zealand, where management procedures are generally viable alternatives to insecticide usage (mob stocking to reduce pasture cover essential to the survival of surface dwelling porina larvae generally present in the summer, the sowing of annula ryegrasses, using infested pasture as run-off, direct drilling of damaged areas, and additional fertilizer applications (French 1973 a, b.), is questionable. All the management procedures for control of this pest are severely limited in hill country areas because of topography (Wilson 1974). The use of spray applications for porina control in this hill-country is generally impractical. This is due to problems such as the topography limiting access and adverse weather conditions, such as characteristic high rainfall and wind run, jeopardising the correct timing, even spread and persistence of applications. Overlapping generations of porina found in the southern North Island hill country also complicates the situation. These factors, together with the low value of hill country pasture compared with the high cost of spray applications of insecticide, make porina control here a high cost/risk operation.

The lower cost, increased persistence and superior spreading qualities provided by bait formulations, as elucidated in the foregoing studies, come some way to answering the inherent problems of porina control in this country with traditional spray applications of insecticides. Additional advantages of baits are that they, have no stock withholding periods and hence do not necessitate the removal of stock from areas treated, a costly operation in itself, are environmentally more acceptable since less insecticide is used, and in certain cases present the opportunity to control other import pasture pests such as slugs. The minimal danger to bird life presented by baits, may be further reduced by the choice of an insecticide which has bird repellant properties e.g. methiocarb.

## 13.2 CONCLUSION:

Results obtained in these studies have permitted the optimal bait density, size and insecticide rate for porina control to be estimated, and field trials have shown that efficient control of porina can be obtained at approximately one quarter of the cost of spray applications. This reduction in cost is accompanied by a reduced risk involved in the efficacy of a bait over a spray application due to the baits superior spreading qualities and increased persistence, making porina control both economically and practically feasible.

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## APPENDIX ONE

TABLE: Faecal pellet numbers and weight eaten, of porina fed with chipped wheat (No.2) at varying temperatures.

| Temperature (°C) | Feeding period (days) | Faecal number (± SE) | Weight (mg) |
|---|---|---|---|
| 5 | 2 | 10.3 ± 2.1 | 13.3 |
| 5 | 4 | 16.4 ± 4.7 | 20.5 |
| 5 | 6 | 23.4 ± 3.8 | 41.0 |
| 10 | 2 | 19.4 ± 3.8 | 26.3 |
| 10 | 4 | 24.1 ± 4.1 | 36.7 |
| 10 | 6 | 36.1 ± 13.0 | 42.0 |
| 15 | 2 | 18.5 ± 2.4 | 31.4 |
| 15 | 4 | 42.7 ± 9.4 | 46.6 |
| 15 | 6 | 47.5 ± 11.8 | 40.8 |
| 20 | 2 | 30.4 ± 6.1 | 32.9 |
| 20 | 4 | 57.7 ± 10.5 | 53.1 |
| 20 | 6 | 43.8 ± 6.4 | 41.0 |

# APPENDIX TWO

## EXAMPLES OF FEEDING PATTERNS IN LUNCH-BOX STUDIES

TABLE : Number of caches taken* in clover and untreated wheat individual feeding arenas, with each replicate. (2 days)

| Box Number | Replicate | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 0 | 0/1 | 0 | 2/1 | 2/1 | 2/1 | 0 | 1/1 | 3/3 | 3/3 |
| 2 | 0 | 0 | 1/1 | 0 | 0 | 0 | 0/1 | 2/1 | 3/3 | 1/3 |
| 3 | 0 | 0/3 | 0/1 | 1/2 | 1/1 | 1/1 | 0 | 1/2 | 0 | 0 |
| 4 | 0/2 | 0 | 1/1 | 1/1 | 3/1 | 0 | 0 | 2/3 | 0 | 0 |
| 5 | 0 | 0 | 3/2 | 3/2 | 3/3 | 1/2 | 0 | 0/1 | 2/3 | 1/2 |
| 6 | 0 | 0 | 0 | 0 | 1/1 | 2/2 | 0 | 0 | 2/2 | 1/1 |
| 7 | 0 | 0/1 | 0/3 | 0/3 | 0 | 0 | 1/1 | 3/3 | 2/3 | 3/3 |
| 8 | 0 | 0 | 1/0 | 0 | 0 | 0 | 2/1 | 1/2 | 3/3 | 3/3 |
| 9 | 0/1 | 0/1 | 0 | 0/2 | 1/1 | 0 | 0 | 0 | 2/2 | 1/0 |
| 10 | 1/0 | 1/0 | 2/0 | 2/0 | 0 | 3/1 | 0 | 0 | 1/1 | 0 |

* The first figure is the number of clover caches removed and the second is the wheat caches removed.

TABLE : Number of food caches taken* in ryegrass and untreated wheat individual feeding arenas with each replicate (2 days)

| Box Number | Replicate | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 1/0 | 0 | 3/3 | 3/3 | 2/2 | 0 | 0 | 0 | 1/1 | 0 |
| 2 | 3/3 | 3/2 | 1/0 | 2/3 | 0 | 3/2 | 3/3 | 0 | 0 | 2/0 |
| 3 | 0 | 2/2 | 3/3 | 3/3 | 0 | 1/0 | 2/3 | 0 | 0 | 2/3 |
| 4 | 2/3 | 2/2 | 3/2 | 0 | 0 | 1/2 | 0/1 | 0 | 0 | 1/1 |
| 5 | 0 | 2/1 | 2/0 | 1/0 | 3/3 | 2/3 | 0/2 | 1/3 | 3/2 | 3/3 |
| 6 | 0 | 3/3 | 2/1 | 0 | 3/3 | 2/2 | 0 | 2/2 | 1/0 | 1/1 |
| 7 | 3/3 | 3/3 | 1/0 | 1/3 | 3/3 | 3/3 | 2/2 | 0 | 3/2 | 3/3 |
| 8 | 1/1 | 1/2 | 2/2 | 3/3 | 0 | 0 | 0 | 2/2 | 1/0 | 1/1 |
| 9 | 0/1 | 0/1 | 0 | 0 | 0/1 | 1/3 | 0 | 1/3 | 3/3 | 0 |
| 10 | 2/1 | 0 | 0 | 0 | 2/2 | 0 | 0 | 1/0 | 3/3 | 1/3 |
| 11 | 3/3 | 3/3 | 0 | 1/3 | 2/3 | 3/3 | 0/1 | 1/0 | 0 | 3/3 |
| 12 | 0 | 3/3 | 0 | 2/2 | 3/3 | 1/2 | 0 | 0 | 3/2 | 0 |
| 13 | 3/3 | 0 | 0 | 3/3 | 3/3 | 3/3 | 0 | 0 | 0 | 1/3 |
| 14 | 3/3 | 1/3 | 3/2 | 3/3 | 3/3 | 0/1 | 3/3 | 3/3 | 0 | 0 |
| 15 | 1/0 | 3/3 | 3/1 | 1/0 | 2/2 | 2/2 | 2/2 | 0 | 3/3 | 2/0 |

* The first figure is the number of ryegrass caches removed and the second is the wheat caches removed.

# APPENDIX THREE

## CHI-SQUARED ($X^2$) TESTS FOR LUNCH-BOX FEEDING STUDIES

White Clover and wheat (untreated) Hypothesis : there is no difference in preference between white clover and untreated wheat.

| Replicates = 130 | Wheat Caches Removed W | Clover Caches Removed C | Total |
|---|---|---|---|
| O | 106 | 125 | 231 |
| E | 115.5 | 115.5 | 231 |
| | 221.5 | 240.5 | 462 |

$$X^2 = \frac{(O-E)^2}{E} = 0.8 + 0.81$$

$$= 1.6 \quad \text{with df=1}$$

Not significantly different to the 5% level $p \approx 0.2$

Perennial Ryegrass and Wheat (untreated)

Hypothesis : there is no difference in preference between perennial ryegrass and untreated wheat.

| Total reps = 206 | White Caches Removed | Ryegrass caches Removed | |
|---|---|---|---|
| O | 278 | 305 | 583 |
| E | 291.5 | 291.5 | 583 |
| | 569.5 | 596.6 | 1166 |

$$X^2 = \frac{(O-E)^2}{E} = 0.6 + 0.6$$

$$= 1.2 \quad \text{with df = 1}$$

Not significantly different $p \approx 0.2$

Clover and Metarrhizium infected wheat:

Hypothesis: That there is no difference between preference to fungal wheat and untreated clover.

| Total reps. 29 | Meta. | Clover | Total |
|---|---|---|---|
| 0 | 27 | 45 | 72 |
| E | 36 | 36 | 72 |
| | 63 | 81 | 144 |

$$X^2 = \frac{(0-E)^2}{E} = 2.25 + 2.25$$

$$= 4.50 \quad \text{with df} = 1$$

Significantly different to 5% level. $p \approx 0.04$

Untreated Wheat and Metarrhizium infected Wheat:

Hypothesis: That there is no difference in preference between untreated and fungicidally treated wheat.

| Total reps. 32 | Untreated | Fungus | Total |
|---|---|---|---|
| 0 | 30 | 2 | 32 |
| E | 16 | 16 | 32 |
| | 46 | 18 | 64 |

$$X^2 = \frac{(0-E)^2}{E} = 12.3 + 12.3$$

$$= 24.6 \quad \text{with df} = 1$$

$p > 0.001$

Fenitrothion Treated Wheat and Untreated Wheat:

Hypothesis: That untreated wheat is not preferred* to fenitrothion treated wheat.

* A bias will occur in favour of untreated wheat since porina will die when a treated wheat is consumed. This may affect the result.

| Total reps = 40 | Treated | Untreated | Total |
|---|---|---|---|
| 0 | 40 | 48 | 88 |
| E | 44 | 44 | 88 |
| | 84 | 92 | 176 |

$$X^2 = \frac{(0-E)^2}{E} = 0.35 + 0.35$$

$$= 0{,}72 \quad \text{with df} = 1$$

Not significantly different $p \approx 0.3$

# APPENDIX FOUR

TABLE : Cover (%) readings from treatment plots at Hauorongo.

| Treatment* | Ryegrass | Clover | Weeds | Bare ground |
|---|---|---|---|---|
| | Type of cover | | | |
| Fenitrothion spray | 93.2 | 18.0 | 8.8 | 7.5 |
| Fenitrothion bait (1) | 98 | 34.6 | 8.8 | 5.8 |
| Fenitrothion bait (II) | 93.4 | 28.4 | 5.4 | 9.0 |
| Fenitrothion + Metaldehyde bait (I) | 65.7 | 6.7 | 6.3 | 16.7 |
| Fenitrothion + Metaldehyde bait (II) | 98.0 | 8.0 | 6.0 | 10.3 |
| Actellic bait (I) | 98.2 | 7.3 | 6.3 | 16.0 |
| Actellic bait (II) | 84.8 | 23.8 | 2.2 | 10.2 |
| Vydate bait (I) | 97.0 | 15.3 | 9.5 | 8.8 |
| Vydate bait (II) | 86.7 | 26.0 | 6.0 | 13.3 |
| Lindane bait (I) | 97.3 | 26.8 | 10.3 | 1.3 |
| Lindane bait (II) | 92.7 | 48.7 | 12.7 | 8.3 |
| Controls Nil | 99.1 | 23.3 | 2.3 | 19.1 |
| (I) | 100 | 27.0 | 5.3 | 10.0 |
| Sawdust (I) | 79.8 | 23.2 | 4.4 | 9.2 |
| Metarrhizium | 95.3 | 21.4 | 6.4 | 9.2 |

* (I) = 1 chip/6.25 $cm^2$

(II) = 1 chip/25$cm^2$

# APPENDIX FIVE

## WEATHER RECORDINGS FOR PERSISTENCE STUDIES

DSIR, Palmerston North data was obtained daily from the 'Evening Standard' newspaper.

TABLE : Weather recordings for each day of the experimental exposure periods

| Period (Day) | Rainfall (mm) | Sun (hrs) | R.H. (%) | Temp.(°C) Min. | Max. | Mini.Temp.(°C) Grass | 10cm | Frost |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 7.4 | 59 | 7.9 | 12.7 | -4.9 | 9.3 | 0 |
| 2 | 1.2 | 4.0 | 82 | 0.3 | 12.6 | -3.5 | 6.0 | 0 |
| 3 | 2.1 | 7.4 | 59 | 7.9 | 12.7 | -4.9 | 9.3 | 0 |
| 4 | 1.2 | 4.8 | 80 | 10.4 | 14.5 | -7.7 | 9.9 | 0 |
| 5 | 0 | 0.4 | 76 | 7.0 | 14.5 | -2.5 | 9.5 | 0 |
| 6 | 0 | 1.0 | 80 | 8.6 | 13.0 | -8.0 | 10.2 | |
| 7 | 5.2 | 4.0 | - | - | - | - | - | - |
| 8 | 1.6 | 6.6 | 87 | 9.3 | 14.0 | 5.9 | 9.9 | 0 |
| 9 | 8.4 | 0 | 86 | 9.9 | 14.6 | 9.1 | 10.9 | 0 |
| 10 | 1.1 | 4.4 | 94 | 9.5 | 14.0 | 6.6 | 9.9 | 0 |
| 11 | 2.0 | 2.0 | 59 | 1.5 | 13.9 | -1.0 | 7.5 | 1.0 |
| 12 | 0.2 | 10.3 | 80 | 7.4 | 11.9 | 3.2 | 9.7 | 0 |
| 13 | 0 | 1.7 | 59 | 4.6 | 14.3 | 0.9 | 8.0 | 0 |
| 14 | 0 | 5.7 | - | - | - | - | - | - |
| 15 | 2.9 | 0.4 | 86 | 7.9 | 13.1 | -7.4 | 9.3 | 0 |
| 16 | 3.4 | 0 | - | - | - | - | - | - |
| 17 | | | - | - | - | - | - | - |
| 18 | 0.1 | 5.8 | 83 | 7.1 | 13.1 | 6.0 | 9.6 | 0 |
| 19 | 1.8 | 3.1 | 87 | 8.5 | 13.5 | 7.2 | 10.0 | 0 |
| 20 | 20.0 | 0.2 | 89 | 10.1 | 12.7 | 8.5 | 11.0 | 0 |
| 21 | 23.0 | 0 | 72 | 10.8 | 13.2 | 9.6 | 12.0 | 0 |
| 22 | 0.7 | 10.0 | 18 | 9.5 | 14.6 | 6.9 | 11.0 | 0 |
| 23 | 1.2 | 5.0 | 86 | 9.3 | 13.9 | -7.1 | 10.5 | 0 |
| 24 | 4.7 | 5.3 | 73 | 8.6 | 14.8 | 6.6 | 10.1 | 0 |

# APPENDIX SIX

## BREAKDOWN OF COSTS IN APPLICATION OF SPRAY AND BAIT FOR PORINA CONTROL

TABLE : Individual costs involved in bait and spray applications (page 92 ).

| | Subject | | Cost |
|---|---|---|---|
| | Fenitrothion (E.C. 60% ai)* | . | $10.50/litre |
| | Unmilled Wheat** | . | $150.00/tonne |
| Spray | - Insecticide (0.9% ai/ha) | . | $15.75/ha |
| | - Aereal application** | . | $31.25/ha |
| Baits | - Insecticide * (0.4% ai/d.wt) | . | $2.28 (1)*** |
| | | . | $0.53 (11) |
| | - Aereal seeding ** (Helicopter) | . | $11.25/ha (1) |
| | | . | $9.38/ha (11) |
| | - Wheat | . | $4.56/ha (1) |
| | | . | $1.14/ha (11) |
| | - Cracking and oil | . | $1.00/ha (1) |
| | | . | $0.25/ha (11) |

* from Hodder & Tolley Ltd, Palmerston North (June, 1981).

** from 'Farm Costs & Prices', MAF, Technical paper 1/81 (1981) 144 pp.

***(1) 1 chip/6.25 $cm^2$

(11) 1 chip/ 25 $cm^2$