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## MOVEMENT OF POTATO MOTH ESTIMATED BY MARK-RECAPTURE EXPERIMENTS

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### ABSTRACT

The movement of potato moth, *Phthorimaea operculella* (Zeller), was investigated using moths marked with fluorescent powder and recaptured with sweep nets and pheromone traps. In a small plot trial sweep netting recovered most marked moths within the release plot, and both sweep and pheromone trap catches declined at distances of 20 and 42 m. In commercial fields, pheromone trap recaptures declined beyond distances of 40 m from the release point, and may have been reduced by natural barriers. Moths were recaptured at approximately 200 m both within the release crop and in separate crops. Use of a standard linear dispersal model with pooled data from all three experiments suggested that only 10% of moths dispersed beyond 200 m, but evidence for this model was not conclusive. These results provide part of the information required for determining suitable locations of susceptible refuge crops which have been proposed for diluting pest resistance to insect-resistant transgenic crops.

**Keywords:** potato moth, *Phthorimaea operculella*, potato, movement, mark-recapture.

### INTRODUCTION

Information on the movement of potato moth, *Phthorimaea operculella* (Zeller), is relevant to the development of pest control strategies including the management of resistance to conventional or transgenic insecticides. Our study has implications for the use of host plant refuges to dilute resistance that may develop if Bt-transgenic potatoes are widely deployed. A range of factors associated with the effectiveness of refugia has been examined for several pests including diamondback moth (Shelton et al. 2000), but there is very little information on potato moth. We have estimated dispersal rates of adult potato moth over short distances ( $\leq 40$  m) (Cameron et al. 2002) but there is little information on movement between commercial crops.

In this study, we performed a small plot experiment to confirm measurements of short distance dispersal, and used pheromone traps to estimate the frequency of longer distance flights, including movement between adjacent and separated commercial potato fields.

### MATERIALS AND METHODS

Mark-recapture experiments were performed by releasing marked moths in a release plot and assessing their movement within this crop and to other crops at varying distances. Individual experiments are described below. General methods and materials for rearing, marking, release and recapture are based on those described in Cameron et al. (2002). Adults for release were collected from cultures, marked and then released on the same day. Fluorescent dust (0.01 g of 'Neon Red') was placed in 30 x 50 cm plastic bags and agitated for 10 s with 40 moths. Marked moths were then released between 1600 and 2100 h, when there was no or minimal wind. Weather records were obtained from the

Pukekohe Research Centre weather station. Recapture was achieved using sweep nets or pheromone traps, and marked moths were detected by examination under UV light for the presence of fluorescent dust. Our interpretation of the results assumes that marked and unmarked moths disperse similarly.

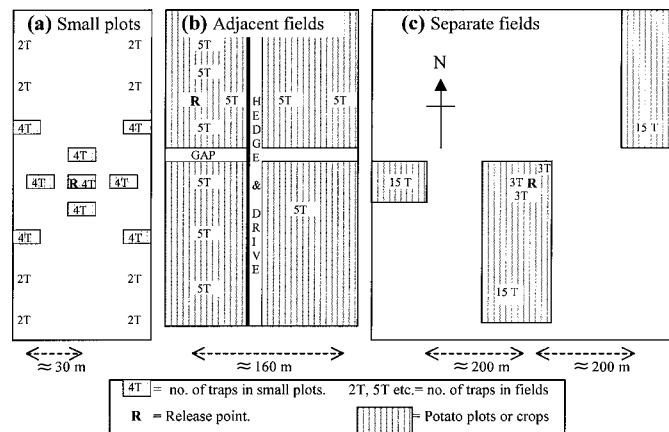
**Sweep netting and pheromone trapping in a small plot trial**

A small plot trial in 2001 at the Pukekohe Research Centre was designed to estimate the distance and direction of movement. Potatoes were planted in 10 x 10 m plots in 1.5 ha of cultivated fallow land to provide a central release plot. Four surrounding plots were centred at a distance of 20 m from the centre of the release plot along the N-S and E-W axes, and a further four plots at a distance of approximately 42 m on the four diagonals (Fig. 1a). A total of 6506 moths with a sex ratio of 0.62 male were released on 20 February. Moths were recaptured one and two days after release by sweep netting in both the release and surrounding plots. Ten samples of 100 sweeps per plot were taken on day one, and 10 x 200 sweeps per plot on day two. The samples were treated with CO<sub>2</sub> and stored at <10°C without removing associated foliage to reduce movement and minimise cross contamination of marked and unmarked moths prior to processing. After these collections were complete on day two, four pheromone traps were placed at the corners of each plot, and a further two traps placed at approximately 80 and 120 m NNW, NNE, SSE and SSW of the release plot (Fig. 1a). These traps were recovered and assessed after three nights.

**Pheromone trapping in commercial fields**

We also assessed movement of marked moths using pheromone traps in two experiments in commercial crops in the Pukekohe area. In March 2001, 2720 moths with a sex ratio of 0.53 male were released in one of four adjacent commercial fields (Fig. 1b). We compared movement within the release field and across minor barriers in the form of a 2 m gap between crops and a 1.5 m hedge associated with a driveway. Sets of five pheromone traps were placed at 40, 80, 160 and 220 m from the release point as indicated (Fig. 1b).

Movement between separate commercial fields at Pukekohe was assessed in February 2002. A total of 2820 moths with a sex ratio of 0.53 male were released at one end of a field (Fig. 1c). Moth movement was assessed with three traps each to the west, south and east at 40 m from the release point, and 15 traps in each of these directions at approximately 200 m (range 160 – 250 m). One set of the more distant traps was within the release field and the other two sets were in separate fields (Fig. 1c). All traps were recovered and assessed after three nights.



**FIGURE 1: Layout of dispersal experiments at (a) Pukekohe Research Centre, and (b & c) commercial crops at Pukekohe, showing release points and pheromone trap positions and numbers.**

For analysis the sweep net data was grouped in pairs to reduce the frequency of zeroes, and the data was standardised to counts per 200 sweeps to enable comparison between days. Analysis for directional and distance effects was performed using ANOVA on the logarithm of one plus the counts per sweep sample and per trap for each distance and direction. Significance tests were made on the means of transformed data, but raw data means are presented for ease of comparison. The relationship between mean pheromone trap catch ( $y$ ) and distance ( $x$ ), over all experiments, was based on an empirical model for dispersal:  $\ln(y) = a - b\sqrt{x}$  (Hawkes 1972), but fitting was done directly to mean trap catches at each distance using a generalised linear model with Poisson error distribution, weighted by the number of sets of traps at each distance. The average dispersal distance and the distance within which 90% of the moths remained were calculated for both the linear and radial dispersal assumptions which are possible for the dispersal model, because some evidence of a simple directional effect was observed for pheromone trap catches in the small plot trial.

## RESULTS AND DISCUSSION

### Small plot trial

The total number of marked moths recaptured in sweep nets over two days was 344, representing 5.2% of the 6560 marked moths that were released (Table 1). This rate was within the range previously recorded (Cameron et al. 2002) for potato moth. The proportion of marked moths recaptured outside the release plot was greater on day two compared with day one, indicating continuing spread of moths. For the combined data at 20 and 42 m, the direction of the plots from the release point was not a significant factor in dispersal (Table 1). However, the number of moths recaptured at each distance was significantly different. Of the total number of moths recaptured, 6.0% were recaptured at 20 m and 2.6% at 42 m, giving a total of 8.6% of moths for a constant catch effort, recovered outside the release area. This percentage is lower than our previous estimates (17.1%, SEM 5.8%) recorded in similar experiments with potato moth (Cameron et al. 2002). In both studies, dispersal was estimated over only two days, so it is likely that further movement would have occurred and that refuges may be effective at greater distances than 20 to 40 m. In other studies, approximately 10% dispersal of moths between fields has been associated with slowed development of resistance to conventional insecticide applications (Caprio & Tabashnik 1992).

**TABLE 1: Marked potato moths recovered by sweeping (mean/sweep sample) or pheromone trapping (mean/trap) at (a) different distances and (b) different directions from the release point in small plot experiments.**

(a) Distance (m)	Sweeps		Pheromone traps	(b) Direction	Sweeps	Pheromone traps
	Day 1	Day 2				
Release plot	38.60	4.50	6.75	W&NW	1.10	2.54
20	2.05	0.80	1.69	N&NE	1.15	1.62
42	0.80	0.43	0.94	E&SE	0.95	1.31
80	-	-	1.00	S&SW	0.88	0.77
120	-	-	0.50			
P	<0.05 <sup>1</sup>	<0.10 <sup>1</sup>	<0.001 <sup>2</sup>		>0.05 <sup>3</sup>	<0.05 <sup>3</sup>
% recovery	3.8	1.4	2.1		5.2	2.1

<sup>1</sup>Compares 20 and 42 m distance on a given day. The catch in the release plot was significantly higher than the catch in 20 & 42 m plots ( $P < 0.001$ ) on both days.

<sup>2</sup>Among distances, pooled over directions at each distance.

<sup>3</sup>Compares catches in four quadrants.

Movement up to 120 m was recorded with pheromone traps. The recapture rate of pheromone traps by comparison with the number of marked males released, i.e. 62% of 6560 or 4018 males, was 2.1%, which was consistent with our previous study. Unlike the sweep net counts, the direction of pheromone traps from the release point was a significant factor in the number of moths recaptured per trap, with capture rates in the W&NW of the trial area being over three times higher than those in the S&SW (Table 1). Further, the mean catch of 1.35 moths per trap in the 20 traps in the north end of the trial area was significantly higher ( $P<0.001$ ) than the corresponding catch of 0.40 moths per trap in the south end. This directionality suggested a preference for moths to fly against the occasional NW breeze present during the study period. The effect of distance of the traps from the release point was significant, showing a rapid decline in catches outside the release plot compared with those within the release plot (Table 1).

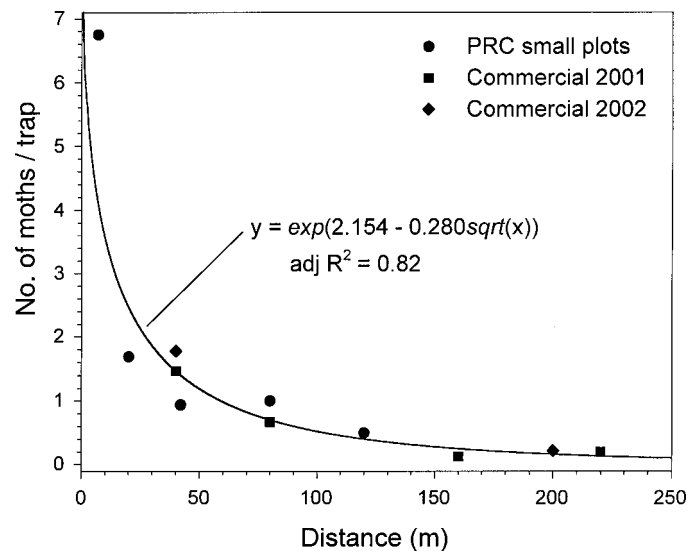
#### Commercial field trials

Marked moths were recaptured at all trap distances in commercial fields, with recapture rates of 2.3% in 2001 and 1.7% in 2002. Over the period of each experiment wind was a minor but variable factor. Similar trap catches in each direction at 40 m (Table 2) indicated that any directional effects did not favour recaptures in particular fields. In both experiments, recaptures declined beyond 40 m and moths were recaptured in traps  $\geq 160$  m distant from release sites. Low catches at greater distances prevented direct statistical comparison of the effects of barriers or distance between crops. The results in adjacent fields (Table 2) suggested that the effect of hedges as barriers to dispersal should be investigated further. However, at distances of around 200 m similar levels of dispersal within the release crop and to separate fields suggested that distance was a more important factor than separation of fields. Overall, recoveries of marked moths indicated low levels of moth dispersal to potato fields within an 8 to 12 ha area.

**TABLE 2: Marked potato moths recovered in pheromone traps (mean/trap) at different distances and directions from the release point in adjacent (2001) and separate (2002) commercial potato fields.**

Direction	Adjacent fields			Separate fields			
	40 m (n = 5)	Barrier	80 m (n = 5)	Direction	40 m (n = 3)	Field	≈200 m (n = 15)
North	1.2	None	0.8	South	1.7	Same	0.33
South	1.2	2 m gap	1.0	East	2.3	Separate	0.20
East	2.0	1.5 hedge	0.2	West	1.3	Separate	0.13

Regression analyses examining the effect of trap distance ( $x$ ) on mean trap catch ( $y$ ) for the combined pheromone trap data for dispersal in small plots and commercial fields showed a significant ( $P<0.01$ ) relationship (Fig. 2). The model used by Hawkes (1972) was found to be appropriate, with no detectable change in intercept (which would reflect differences in population sizes, duration or timing of trapping, or moth survival) or slope (dispersion rate) among the three trials. The fitted equation is:  $\ln(y) = 2.15 - 0.280 \sqrt{x}$ , with standard errors of the parameters being 0.447 and 0.066 respectively. This relationship estimated the mean dispersal distance of marked moths as 76 and 255 m for linear and radial dispersion respectively, and indicated that to achieve 10% dispersal between fields, separate crops should be planted within 190 or 570 m of each other for the respective models. If moths disperse randomly in any direction the radial model is applicable, and this implies that growers should insert refuges within or among transgenic crops to maximise interception of moths. If moths prefer to fly upwind or downwind, fly along barriers, or fly towards nearby potato crops, the linear model is more appropriate. This model may best represent the situation in our "separate crop" example. Data obtained from these trials suggest that direction is a factor, but that the simple linear model is over simplistic. Overall,



**FIGURE 2: Effect of distance from the release point on the mean number of marked potato moths recaptured per pheromone trap.**

the models indicate the potential range of dispersal and suggest that it would be prudent to place separate refuge crops within 200 m of other commercial crops, pending more information on moth dispersal patterns. Finally, the significance of this level of dispersal for gene flow between crops also depends on the population levels and mating of potato moths in each field. These levels in turn will be determined by the effectiveness of various control techniques, including Bt-crops, IPM procedures or conventional controls.

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