USE OF PHEROMONE TRAPS AS INDICATORS OF THE SPECIES COMPOSITION OF HELIOTHIS EGGS LAID IN COTTON CROPS.

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Introduction

As an aid to the management of Heliothis in cotton, the use of both pheromone and light traps for monitoring populations has received considerable attention. While their use is, as yet, unlikely to replace routine crop scouting there has been much progress in the development of the most efficient trap designs and in the assessment of environmental factors which influence trap catches (Rothschild et al 1981). These studies, carried out largely by Angus Wilson (CSIRO, Division of Plant Industry), are crucial to the interpretation of trap catches in terms of real changes in the abundance or behaviour of Heliothis populations.

Catches in pheromone traps can provide two types of information of interest to growers and researchers. Firstly trap catches may directly indicate the abundance of moths in an area and hence the level of egg laying in the crop. Unfortunately there doesn't appear to be any close association. Despite accounting for the effects of temperature and wind speed, Rothschild et al (1981) found the relationship between trap catches (in cannister traps) and egg numbers was too variable on a day to day basis to be a reliable indicator of oviposition activity. Twine (1982), using texas traps, found similar results in two seasons of monitoring on the Darling Downs.

Secondly, pheromone traps may be used as a guide to the species composition of eggs laid in the crop. This aspect has received less attention but the differential effectiveness of some insecticides on H. armigera and H. punctigera, and more importantly the emergence of pyrethroid resistance in H. armigera, add to the need for a reliable measure of the species composition of eggs. In this paper we examine the reliability of pheromone traps as indicators of the species composition of eggs from a study of 20 sites in four cotton growing areas. In addition we examined variation between farms in the proportions of *H. armigera* and *H. punctigera* in egg lays occuring at the same time. An estimate of this spatial variability is relevant to the possible use of a small number of monitoring sites to indicate patterns of relative abundance of the two species over entire cotton growing regions.

Methods

The relationship between pheromone trap catches and *Heliothis* oviposition was examined intensively over the whole season at 3 sites in the Namoi Valley and less closely at another 17 sites in the Namoi, Macquarie and Gwydir Valleys and on the Darling Downs. The intensively studied sites were 5-7 km apart in the vicinity of Narrabri Agricultural Research Station. At each of these sites four cannister or dry funnel traps were established, two each for *H. armigera* and *H. punctigera*. Pheromone lures were renewed every four weeks and the traps were cleared three times per week. At these times the densities of *Heliothis* eggs and larvae were also recorded by the examination of 30 whole plants. Battery powered light traps were operated at each site on three nights per week. Samples of eggs were collected whenever densities exceeded 10/metre of row. Care was taken not to bias sampling in favour of one part of the plant (e.g. terminal leaves), by careful searching of both old and young leaves, squares and stems.

Additional data was obtained from egg collections at 12 sites in the Namoi, 3 in the Gwydir, 2 in the Macquarie and 3 on the Darling Downs. Each of these sites had a pair of pheromone traps, one for each species, maintained as part of the SIRATAC system. Eggs were usually collected only when heavy egg lays occurred.

When possible 200-300 eggs were collected from each site at each collection. They were transferred to individual containers of artificial diet before hatching and the species composition was determined by the identification of 3rd-4th instar larvae. In some cases eggs were identified using an electrophoretic technique developed by Dr. J. Daly (CSIRO Entomology). The entire data set represents the identification of some 6918 larvae in 58 collections from 20 sites. For each collection the percentage of identified larvae belonging to each species was compared with the percentage caught in pheromone traps over the four days prior to or after the eggs were collected. Data was analysed by linear regression after angular (arcsine) transformation of both the dependent and independent variables.

Results

Expectations

If pheromone traps provide an unbiased estimate of the species composition of Heliothis in a crop we would expect a linear relationship between % H. armigera in the traps and the % H. armigera eggs on the crop, as shown in Figure 1. Points should fall in an ellipse around a straight line with slope (b) of 1 (i.e. 45^o angle) passing through the origin (i.e. 0% in traps = 0% in eggs). This expected relationship incorporates a number of assumptions:-

1. a 1:1 sex ratio of both species in the local population
2. that H. armigera and H. punctigera females lay similar numbers of eggs.
3. that traps are equally efficient in attracting and catching males of the two species
4. that the method of collecting eggs is not biased in favour of one or the other species
5. that mortality of eggs and small larvae from the time of collection until they are large enough to identify is equal for the two species

For a local population, Assumption 1 is probably valid but at the scale of individual cotton farms or management units we do not as yet have any data on the relative distribution of sexes in the two species. Assumption 2 seems quite valid based on laboratory estimates of fecundity. Bias in the collection of eggs (Assumption 4) also seems unlikely particularly for the intensively studied sites which make up over half the data set. As yet no detailed data on Assumption 5 is available but there seems no reason to expect differential mortality in the laboratory. Thus the main assumption tested here is the relative trapping efficiency of pheromone traps for H. armigera and H. punctigera.

Relationship between Species Composition in Pheromone Traps and in Egg Lays

In an effort to compensate for any lag period in trap catches relative to egg laying we compared the species composition of eggs with that in trap catches over the four days preceding the collection and over the four days after it.

Figure 1 shows the data points in relation to the expected lines. Clearly the pheromone traps, in most cases, did not give an accurate estimate of the relative abundance of the two species. Most often the traps overestimated the proportion of H. armigera (or alternatively underestimated the proportion of H. punctigera). This was true irrespective of whether catches before or after the collection date were used. Calculated linear regressions are shown on the figure. In both cases the slope of the fitted line is significantly less than 1, though the 'Y' intercept is not significantly different to zero. More importantly, although these relationships are statistically significant, there is a high level of variability around them (low r^2). For instance trap catches of 90-100% H. armigera were associated with egg collections ranging from 9.7-100% H. armigera. In fact for catches of between 0-80% H. armigera there is no relationship between the species composition in the traps and in egg lays. The high level of variability around the relationship indicates that the regression coefficient (b) cannot be used with confidence as a correction factor to adjust pheromone trap catches. Trap catches for days after the eggs were collected always gave a worse fit than those before and for logistic reasons they are unlikely to be of much practical importance. All the following discussion refers only to catches for the 4 days before the collection.

As indicated earlier a number of factors, besides the efficiency of traps, may influence the relationship between relative trap catches and egg lays. In the SIRATAC program, pheromone trap catches are not considered if the rate of catch is <5 moths/day. In our data set, catch rates ranged from 0.2-58.4 H. armigera/trap/day. We therefore eliminated all points with a catch of <5/day. This procedure did not improve the relationship markedly (Figure 2); the slope remaining significantly less than 1. In fact the relationship was poorest when only catches of >15/day were considered ($y = 0.56x - 15.43$, $r^2 = 0.28$).

Another factor which may have influenced the relationship is differential rates of egg hatch and early larval survival for the two species. The season was characterised by great variability between collections in egg hatch and survival, with a mean of 58.54% overall (range 12.9% - 95.4%). If for some unknown reason H. armigera eggs and larvae were less likely to survive than H. punctigera, trap catches would appear to show a bias in the direction observed. This question could not be addressed directly but instead we divided the collections into those with high egg and larval survival (>60%) and those with low survival (<60%). Mean survival to 3rd-4th instar in the two categories was 76.6% (n = 31) and 37.8% (n = 27) respectively. As Figure 3 shows the relationship was poor in both these categories. Further analyses showed that the prediction of species composition of egg lays from trap catches can be improved if daily minimum temperature is also considered. However, other climatic variables (max temperature, windspeed) did not improve predictions. Further work on these effects may allow a correction factor for trap catches to be introduced in the future.

Relationship between Species Composition in Light Traps and Egg Collections

For the three sites monitored intensively, catches in light traps gave a more reliable indication of the species composition of egg lays than did pheromone traps at the same sites (Figure 4). It is interesting to note also that data from the Myall Vale light trap when used for comparison with eggs collected at these sites (which ranged from 1-5 kms away) gave a better indication of the species composition than did the pheromone traps at those sites.

Spatial Variability in Relative Abundance of H. armigera and H. punctigera

The egg collections made for this work, and others taken for monitoring the frequency of pyrethroid resistant *H. armigera* in the Namoi Valley, showed that there may be considerable spatial variation in the proportions of the two species among collections made on the same day (Table 1). In some cases the variation was minor, but in others the range was considerable. This variability was evident even among sites within 1 km of each other, and may reflect real differences in the relative abundance of moths or in the relative attractiveness of crops for the two species. More importantly it indicates that any technique used to assess the species composition of egg lays should be applied on individual farms. A small number of monitoring sites in a region may not give a reliable indication for all farms at any particular time. This is particularly so if the threshold proportion of a species at which some management decision is to be taken is low (e.g. no pyrethroids if *H. armigera* is >5%).

Conclusions

A multitude of environmental factors (temperature, wind speed) and crop characteristics (phenology, nectar production, genotype etc) influence both trap catches of males and the oviposition behaviour of female *Heliothis*. Since males and females may respond in different ways to these factors it is perhaps not surprising that there is no more than a general relationship between trap catches and the level of oviposition activity. However, our results also suggest that pheromone traps may be unreliable indicators of the relative abundance of *H. armigera* and *H. punctigera* as well.

The most simple explanation for the apparent bias in trap catches is that the synthetic pheromone of *H. armigera* is more efficient at attracting males than is that of *H. punctigera*. Given the relatively recent identification of pheromone components for both species it is probable that the pheromone blends currently in use are not yet ideal and future modifications may see an improvement in their relative attractancy. The efficiency of the more complex pheromone of *H. punctigera* (3 components, compared with 2 for *H. armigera*) may also be more sensitive to environmental factors. Alternatively bias may result from slight differences in the movement patterns or behaviour of male moths when responding to pheromone sources, with the result that a smaller proportion of the *H. punctigera* which respond to the traps are actually caught. Slight changes in trap design may remove this bias.

Bias could also result from differences in the structure and behaviour of the female section of the population. If, for example, a larger proportion of the female population of *H. punctigera* enters the crop already mated and unaccompanied by an influx of males the observed bias could easily result because the relative numbers of males caught would not indicate the relative numbers of egg laying females.

The points outlined above emphasise the need for a thorough understanding of the behaviour of *Heliothis* populations in relation to monitoring systems and changing characteristics of the crop. Such studies are now underway.

References

Rothschild G.H.L., Wilson A.G.L., Malafant K.W. (1981) Preliminary studies of the female sex pheromones of Heliothis species and their possible use in control progrmas in Australia. ICRISAT Conference Proceeding pp. 319-327.

Twine P.H. (1982) The suitability of Heliothis pheromone traps in pest management programmes. ACGRA Research Conf. Proceedings pp. 106-108.

Table 1. Spatial variation in the proportion of *H. armigera* in egg collections made in the Namoi Valley over a 1-2 day period.

REGION	COLLECTION DATE	SUB-REGION	NO. SITES	RANGE IN % ARMIGERA
NAMOI	Dec 14-15	East	3	19 - 50
		West	4	10 - 26
	Dec 18-19	East	3	8 - 28
		West	3	5 - 17
	Dec 30	East	2	0 - 5
		West	2	0 - 7
	Jan 12-13	East	3	2 - 24
		West	4	3 - 20
	Jan 25-26	East	6	1 - 7
		West	2	1 - 10
	Feb 8-9	East	2	42 - 46
	Feb 10	East	5	7 - 22
		West	7	0 - 10
	Feb 15-16	East	4	3 - 16
		West	2	0 - 9
	Feb 17	West	8	1 - 22
	March 21-22	West	6	20 - 59
MOOMIN	Feb 8-9	Lower	4	10 - 49
	March 21-22	Lower	3	17 - 81
		Upper	6	24 - 73
MACQUARIE	Feb 6		5	5 - 28
	March 27-28	-	4	12 - 51

East - Namoi sites east of Wee Waa, West - Namoi sites west of Wee Waa.

FIG. 1.

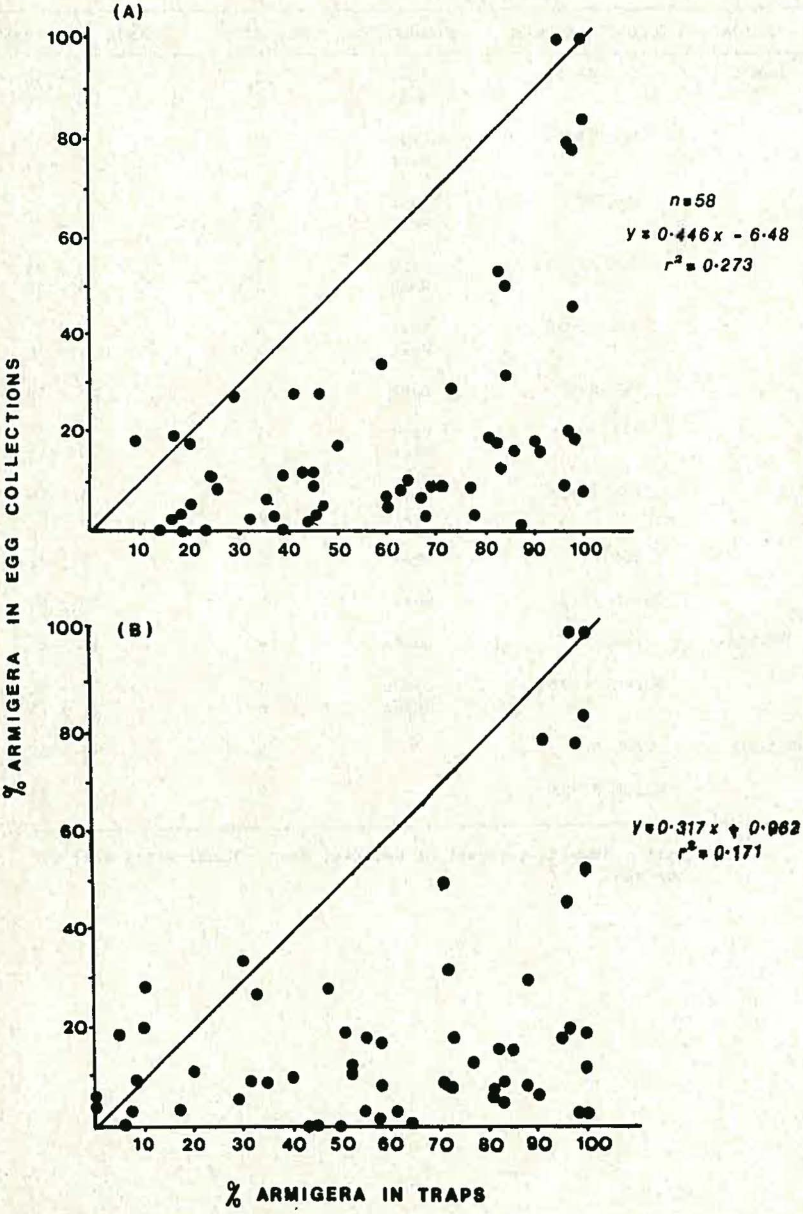

(A)
100
80
60
40
20
10 20 30 40 50 60 70 80 90 100
n = 58
y = 0·446 x - 6·48
r² = 0·273
(B)
100
80
60
40
20
10 20 30 40 50 60 70 80 90 100
y = 0·317 x + 0·962
r² = 0·171
% ARMIGERA IN EGG COLLECTIONS
% ARMIGERA IN TRAPS

FIG. 2.

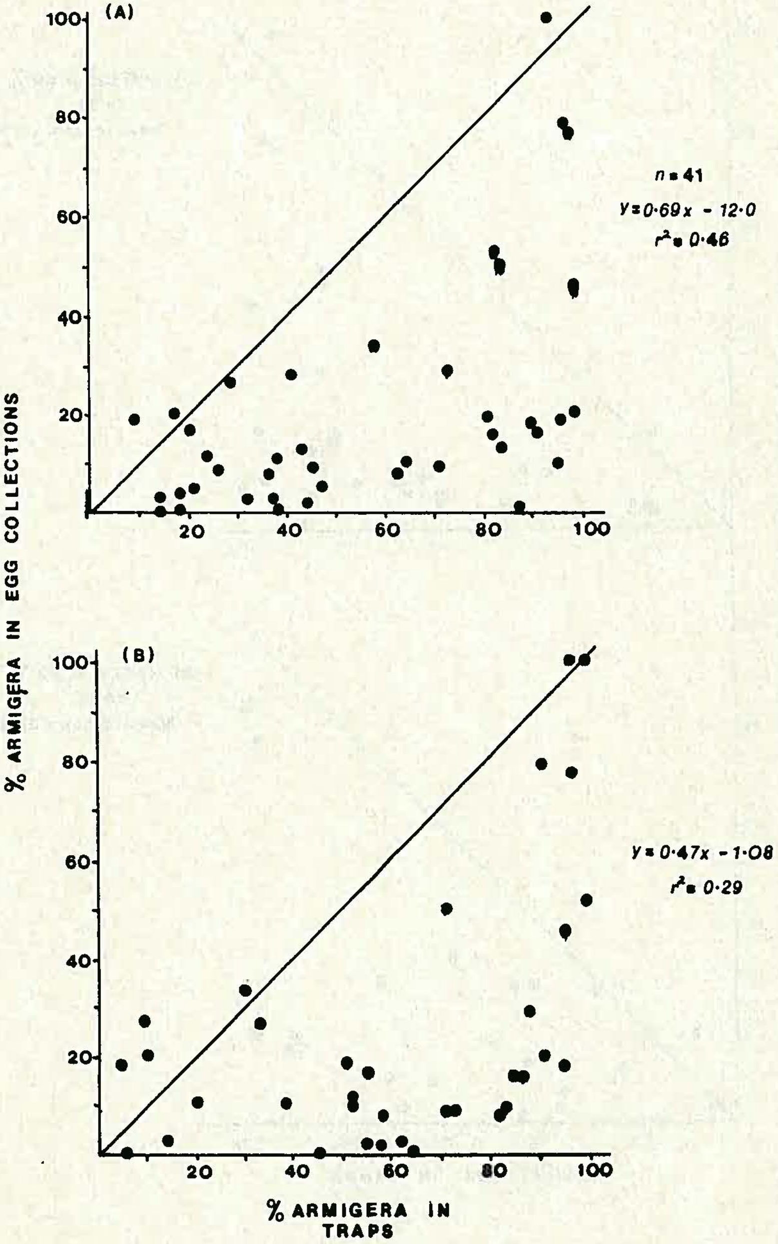

(A)
100
80
60
40
20
20
40
60
80
100
n = 41
y = 0·69x − 12·0
r² = 0·46
% ARMIGERA IN EGG COLLECTIONS
(B)
100
80
60
40
20
20
40
60
80
100
y = 0·47x − 1·08
r² = 0·29
% ARMIGERA IN TRAPS

FIG. 3

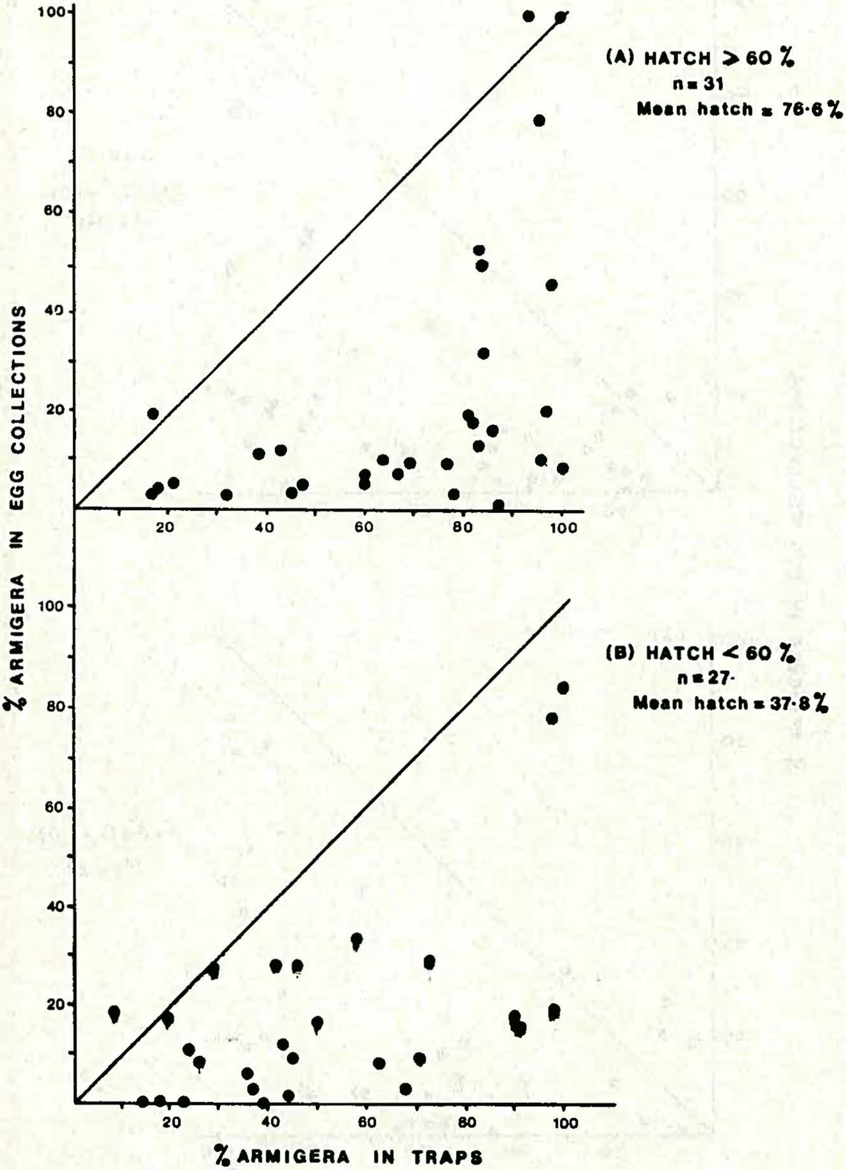
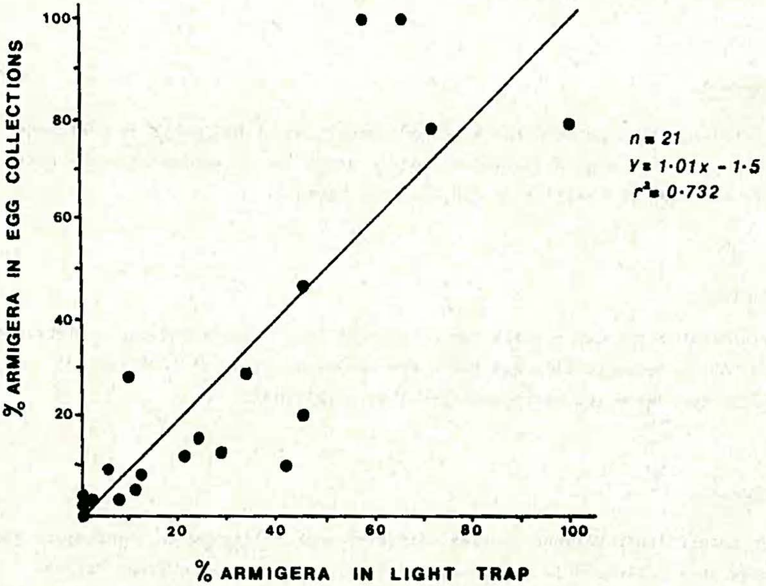

% ARMIGERA IN EGG COLLECTIONS
100
80
60
40
20
20
40
60
80
100
(A) HATCH > 60 %
n = 31
Mean hatch = 76·6 %
100
80
60
40
20
20
40
60
80
100
(B) HATCH < 60 %
n = 27
Mean hatch = 37·8 %
% ARMIGERA IN TRAPS

FIG. 4-


% ARMIGERA IN EGG COLLECTIONS
100
80
60
40
20
% ARMIGERA IN LIGHT TRAP
20
40
60
80
100
n = 21
Y = 1·01x - 1·5
r² = 0·732

LEGEND TO FIGURES

Figure 1.

The relationship between the species composition of *Heliothis* in pheromone traps and among eggs collected in cotton crops: (A) using the total trap catch for the four days prior to the egg collection, (B) using the total catch for the four days after the egg collection. In both cases the slope of the line is significantly less than 1 ($p<0.05$).

The diagonal line is the expected relationship between the two variables if pheromone traps are unbiased.

Figure 2.

The relationship between the species composition of *Heliothis* in pheromone traps and among eggs collected in cotton crops for occasions when the catch rate was >5moths/trap/day. A and B as in Figure 1.

Figure 3.

Relationship between species composition of trap catches and egg collections for (A) collections with egg hatch and larval survival of >60% and (B) collections with egg hatch and larval survival <60%.

Figure 4.

The relationship between species composition of *Heliothis* in light traps and among eggs collected in cotton crops at three sites in the Namoi Valley.