

7/85-6/91 ✓ A 91

88/1260

COTTON RESEARCH AND DEVELOPMENT CORPORATION

Project Title: Quantifying Local Movement and Colonisation of Cotton Crops By Adult *Heliothis*.
Project Code: CSE3C
Supervisor: Dr. G.P. Fitt, CSIRO Division of Entomology, Narrabri.

FINAL REPORT

Aims:

- (i) to quantify the contribution of alternative host crops to the dynamics of *Heliothis* on cotton using an elemental analysis technique developed in a previous project.
- (ii) to study the colonisation of cotton crops by adults and subsequent development of populations using night vision devices, pheromone and light traps and direct sampling techniques.
- (iii) to quantify the catch efficiency of pheromone traps and factors affecting efficiency in cotton at different times of the season.
- (iv) to study patterns of local movement from discrete source crops, using mark-recapture, elemental analysis, night vision devices and trapping systems.

1. Quantifying intercrop movement using elemental analysis.

A technique to identify the host crop of *Heliothis* moths by analysis of elemental content has been progressively developed over several seasons (CRC Project CS13L, Fitt 1986). In this grant period we finalised statistical analyses of the existing database for individuals from known hosts and have developed a procedure for allocating unknown individuals collected in cotton crops to probable hosts (developed by Dr. Richard Morton CSIRO Biometry Unit). The procedure (based on Newton's method with gradient matrix calculated by formula) allows for moths to be allocated to one of five major host crops or to a class derived from none of the major crops and includes a facility to use only a subset of possible hosts in an allocation run. The procedure gives acceptably accurate estimates of the proportion of a sample of moths derived from major hosts, though to date it has been validated using the same database as used to produce it. Further data for individuals from known hosts is being collected this season for validation purposes. We have commenced processing elemental data for unknowns collected in 1985/86 using the procedure but have encountered a problem which may be due to dust contamination of field caught moths. The elements Fe, P, and Mn are the most important in discriminating moths from different crops (accounting for 85-90% of the variation), but most of the moths taken from traps show levels of Fe (and Al and Si) outside the range of any of those reared from crops, while levels of other elements are similar to those for moths reared on

RS 28/3/92

crops. Elevated concentrations of Fe, Al and Si are characteristic of sample being contaminated with soil, which may easily occur in pheromone traps from which the moths are collected.

There are several other possible explanations for this anomaly; elemental profiles may change as moths age, mated males may have a different profile to virgins, or flight activity may alter the balance of elements. These possibilities were explored with a series of experiments using male *H. punctigera* moths from a chickpea crop. Elemental profiles were determined for males of different age, for mated and unmated males of known age and for "flown" and unflown males. As yet these results have not been fully analysed, but it may be necessary to rework the allocation procedure excluding Fe, albeit with considerable loss of discrimination. Elemental analyses of moths collected at several sites in cotton over the 1985/86 to 1987/88 have been completed. Analyses of the 1988/89 samples will commence shortly giving elemental profiles over four full seasons. The information provided in this way will be invaluable to validation of the *Heliothis* population dynamics model and for interpreting past patterns of insecticide resistance in *H. armigera*.

2. Nocturnal behaviour and measurements of trap responsiveness.

In 1988/89 a 10 ha block on the research station was sown with two 4 ha. blocks of cotton separated by 1 ha. blocks of maize and pigeon pea. The maize (sown Sept. 19) produced an emergence during January, while the pigeon pea (sown Dec. 16) produced adults in early March. The development of populations on all crops was monitored by visual sampling for eggs and larvae and by a grid of pheromone and light traps. One period of nocturnal observations using Night Vision Goggles (NVG) was completed (Dec. 14-18) coinciding with silking of the maize crop. The aim was to quantify the densities of *Heliothis* adults active throughout the night within each crop and at crop boundaries and to measure the efficiency of pheromone traps.

Unfortunately the general scarcity of *Heliothis* throughout the Namoi Valley in 1988/89 greatly limited the success of this work. Very few eggs were laid on any crops and only small populations of pupae were produced on the maize and pigeon pea. Nocturnal observations were discontinued after the December session, except for a few nights during February and March.

In the second season (1989/90) an 8 ha block on the research station is being used. This was sown with 4 ha of cotton (2 ha on each end), and 2 ha each of maize and pigeon pea. Again the maize will produce a January emergence of *H. armigera* and the pigeon pea a March

emergence. An additional 8 ha block was sown with chickpea to allow observations of the development and emigration of a spring population.

Two periods of intensive nocturnal observations were completed. During each period a series of observations were made using a variety of techniques, some associated with Project CSE7L. The first period of nocturnal and radar observations was completed (November 29-December 12) coinciding with emergence of the approximately 1.3 million moths from the chickpea (a mixture of *H.punctigera* and *H. armigera*) and the start of silking of the maize. Most details of the nocturnal observations and measurements of activity and movement are described in Drake and Fitt (1990, attached).

Data was collected for the first time on the timing of adult emergence from the soil throughout the night and of the initial flight. Emergence occurred from 2000 to 0100, with a peak between 2100 and 2200. Most moths took off on their initial short flight about 2 hours after emergence. In general these flights do not take the moths far from the emergence site. Major take-off and emigration from the emergence site occurs at dusk on the following night. We also quantified this dusk take-off for comparison with the radar observations, by recording the number of moths undertaking rapid vertical flight out the chickpea. We were able to confirm that such vertical take-off does occur, with moths climbing almost vertically to about 10 metres above the crop, thence climbing at about 60° in the direction of the prevailing wind. Peak vertical take-off occurred between 2010 and 2025 each night, though there was great variability in numbers taking off each night, which was not related to the numbers which had emerged the previous night. Similar observations will be made during the January and March emergence periods.

An important consequence of our direct observations of moths behaviour around crops has been the discovery of a previously undescribed behaviour in *Heliothis* in which adults turn back, or rebound, into an attractive crop when they encounter the patch boundary. The behaviour was first observed at boundaries between maize and cotton crops and between cotton and fallow. Observations in the 1990/91 season further confirmed the occurrence of the behaviour at boundaries of maize/ sunflower, sorghum/cotton and sorghum/sunflower crops both at NARS and at sites on the Breeza Plain and near Toowoomba. Rebounding into the crop was most intense around silking maize crops and much less pronounced on the other crops. The observations show that moths are able to perceive and respond to crop boundaries and that their movements may be effectively constrained to an attractive host patch once colonisation has occurred. Whether moths respond to the physical boundary or some chemical gradient is not yet known, though the rapidity of response (within 1 m of the edge) suggests a response to the physical edge of the canopy. This may explain why the behaviour was most pronounced on maize (the tallest crop observed). The observations warrant further investigation and have

implications in understanding the process of host location and the use of trap cropping as a means of managing *Heliothis* (3,4).

Measurements of pheromone trap efficiency were made at monthly intervals during 1989/90 season. As in the past canister traps proved highly inefficient at all times, capturing only 2-5% of moths attracted to them. These spring trap observations confirmed that the characteristically high trap catches at that time are not due to improved trap efficiency when nights are cooler, but reflect enormous densities of moths. Males were observed responding to traps at temperatures as low as 7°.

3. Mark-recapture studies of *Heliothis* movement.

Mark-recapture studies of moth emigration from source crops were conducted in spring of both 1989/90 and 1990/91 to coincide with the other observations of emergence and local movement. The aim was to label each of the source crops with the heavy metal strontium (in the form of strontium chloride, SrCl_2) in an attempt to mark the naturally produced population of moths. Chemical analysis of moths trapped in a widespread network of traps then shows the direction and distances travelled by moths produced at the discrete source. Preliminary studies were conducted in 1988/89 with maize and pigeon pea. Labelling of the maize crop with two applications of SrCl_2 (@3.0 kg/ha) was unsuccessful; only 1 of 50 moths analysed being marked. However, excellent results were obtained with pigeon pea. A range of concentrations from 10 to 80 kg SrCl_2 was applied. Plant tissues and 90-95% of the adult moths produced were unequivocally marked by applications of 10-20 kg/ha. However, the total population produced on pigeon pea in that year was too small to consider a mark-recapture experiment.

In the 1989/90 a highly successful experiment was completed with a marked population of both *H. armigera* and *H. punctigera* produced on a spring crop of chickpea. All details of this work are given in Fitt and Pinkerton (1990, attached). A total of 1.2 million moths (38% *H. armigera*, 62% *H. punctigera*) were produced from the chickpea crop, of which about 30% were unequivocally labelled. Of these 240 labelled *H. armigera* and 28 labelled *H. punctigera* were captured in the trapping network. Further analyses of these results (6) showed that *H. armigera* was less mobile than *H. punctigera* with a high proportion settling on crops within 10km of the source crop, whereas most of the *H. punctigera* moths appeared to leave the study area altogether.

Attempts in that season to label a population of *H. armigera* on maize were again unsuccessful.

In the 1990/91 season a mixed population of *Heliothis* was again successfully labelled on chickpea. This crop produced an estimated 1.04 million moths (73% *H. armigera*, 27% *H. punctigera*). A total of 4,340 captured moths from the recapture network were analysed for strontium. However, because the background population of *Heliothis* spp. was much larger in that year (in contrast to 1989/90), a total of only 19 marked moths were captured (in contrast to 268 in the previous season). Detailed statistical analysis of this experiment is not yet complete.

Major Results from This Project.

1. Nocturnal observations of *Heliothis* activity using a variety of techniques provided valuable details and parameters needed to model movement in the associated Project CSE5C.
2. A previously undescribed behaviour pattern was observed in adult *Heliothis* which shows that moths are able to perceive and respond to boundaries and that their movements may be effectively constrained to an attractive host patch once colonisation has occurred.
3. The timing of emergence and first flight were quantified for the first time for Australian species, showing a peak of emergence between 2100 and 2200. First flight occurred approximately 2 hrs after emergence.
4. Mark-recapture was used successfully to demonstrate significant differences between *H. armigera* and *H. punctigera* in local movement. *H. punctigera* was confirmed to be more mobile than *H. armigera*, and may be an obligate migrant species. Both species were shown to be able to locate and colonise small areas of highly attractive hosts (safflower) despite the presence of large areas of squaring cotton. Further studies of *H. armigera* movement during summer will be undertaken under a new project CSE24C.

References

1. Drake V.A., and Fitt, G.P. (1990) Studies of *Heliothis* mobility at Narrabri, summer 1989/90. Fifth Australian Cotton Conference 1990, Surfers Paradise, pp. 295-304.
2. Fitt G.P. (1986) The use of elemental analysis as a tool in the study of intercrop movement by adult *Heliothis*. pp. 207-213 in Proc. Australian Cotton Growers Research Conf. Surfers Paradise, 1986.

3. Fitt G.P. (1989) The ecology of *Heliothis* species in relation to agro-ecosystems. *Annu. Rev. Entomol.*34:17-52.
4. Fitt, G.P. (1991) Host selection in Heliothinae. Chapt. 7 in "Reproductive Behaviour in Insects - Individuals and Populations" J. Ridsdill-Smith and W. Bailey (eds.), Chapman and Hall.
5. Fitt G.P. and G. Boyan (1991) Methods for Studying *Heliothis* Behaviour. Chapt. 11 in "*Heliothis* : Research Methods and Prospects", M.P. Zalucki (ed), Springer-Verlag.
6. Fitt, G.P. and A. Pinkerton (1990). A mark-recapture study of *Heliothis* movement from a source crop in the Namoi Valley. Fifth Australian Cotton Conference 1990, Surfers Paradise, pp. 283-293.