A 88 ✓7/87-6/1988 1988/CS21C .12

FINAL REPORT FOR COTTON RESEARCH COMMITTEE PROJECT CS21 OF 1985/86: "RADAR AND NIGHT VISION DEVICE OBSERVATIONS OF *HELIOTHIS* MOTH FLIGHT AND MIGRATION".

Grantee: CSIRO Division of Entomology (Dr V. A. Drake).

C.R.C. cost code: X06CB.

Date: 17 December 1986.

Scientific personnel

The following research scientists participated in the project fieldwork:-

Dr V. A. Drake	CSIRO Division of Entomology	
Dr R. A. Farrow	" " " "	
Dr J. C. Daly	" " " "	(part time)
Dr A. Sparks	USDA Insect Biology and Population Management Lab.	
Mr W. Wolf	" " " " " " "	

Support for these scientists in the field was provided by four technical officers of the Division of Entomology. Dr Daly was simultaneously undertaking field work for her project "Ecological genetics of pesticides resistance in *Heliothis armigera*" and was assisted in this work by an additional Division of Entomology technical officer.

Funding

Salary costs and overheads for all CSIRO participants except Dr Daly were met from CSIRO appropriation funds, and the equivalent costs for the USDA participants from USDA. Dr Daly's salary was met from Cotton Research Committee grant C10. Travel costs for Dr Sparks were met by USDA. Mr Wolf's participation formed part of his activities as a Fulbright Senior Scholar, and his expenses were met by the Australian-American Educational Foundation.

The Cotton Research Committee grant C21 of $20 500 was used to meet the costs of:-

1) travel of CSIRO participants;
2) vehicle fuel and maintenance, and vehicle hire;
3) aircraft hire;
4) materials and services (e.g. radar film and film-processing).

135

CSIRO

Division of Entomology
Black Mountain, Canberra, ACT

A Division of the Institute of Biological Resources

PO Box 1700, Canberra City, ACT 2601
Telephone (062) 46 4911
Telex AA 62309

VAD:jw
Ref : SB3/9/85

85/86
CS21
85/1056

18 December 1986

The Secretary
Cotton Research Council
Department of Primary Industry
CANBERRA ACT 2600

Dear Sir

I am pleased to enclose the final report for Cotton Research Council project C21 of 1985/86, "Radar and night vision device observations of *Heliothis* moth flight and migration". This was a one-year project which has now terminated.

A copy of the proposed publication will be forwarded as soon as it becomes available.

Yours sincerely

V A Drake

V A Drake
(Insect Migration sub-program)

This grant was underspent by \$6 955, mainly because operations, and especially aircraft flights, were curtailed once it became clear that no additional significant results were likely to be obtained. A detailed account of expenditure has been provided in a "Statement of Receipts and Expenditure" already submitted.

Project objectives

To determine the nature and extent of migratory flight in *Heliothis armigera* and *Heliothis punctigera*, and to estimate the significance of migration in the formation of outbreaks and in the spread of insecticide resistance in these pests.

Work undertaken

An intensive series of observations were made in the Emerald, Queensland, cotton-growing region between 1 and 19 February 1986. The following methods of studying *Heliothis* movement were employed:-

1) *Radar*. The CSIRO Entomological Radar was used to observe night-time flights of insects at heights up to 1 km. Observations commenced at dusk and continued on most nights until after midnight. The density, direction, and speed, of migration at a series of heights were measured at frequent intervals, and a film record of the radar display obtained. Recordings of the wingbeat modulations of the radar echoes from the insects were made on several occasions. More limited observations were made during the day, when insect activity was generally slight. Measurements of the radar reflectivity of individual *Heliothis* moths and other insects were also made.

2) *Visual observations*. Dusk take-off was observed through binoculars. Later in the night, flight at altitudes of 10-30 m was measured by counting the number of moths passing through a vertical light beam, using night-vision goggles. The goggles were also used to make qualitative observations of night-time moth activity in cotton and other host crops.

127

3) *Sampling.* A number of techniques were used to obtain samples of the insects observed visually and with the radar:-

a) *Vehicle netting.* A giant vehicle-mounted net, specially developed by the Division of Entomology for this project, was used to sample moths and other insects flying at altitudes of 2-4 m. The vehicle carrying the net was driven along two routes, one running between cotton crops and the other in a fallow field at the edge of the irrigation area. Each route was about 3 km long, and several samples were obtained on most evenings.

b) *Flight trapping.* A "goal-net trap", a giant flight trap with an aperture of about 25 m^2 centred 5 m above the surface, was constructed for this project. The trap was erected at the edge of a cotton field and sampled insects flying downwind into the field. It was operated on the majority of nights, but could not be used when the wind was strong.

c) *Light-trapping.* A small light trap located at the top of a 25-m tower, and fitted with a shield so as to be visible only from above, was used to sample insects flying at altitudes of a few tens of metres.

d) *Kite-borne net trapping.* Insects flying at altitudes of 100-200 m were sampled with a net flown from a kite. Samples were obtained on the majority of nights, but the kite and net could not be operated when the wind was either too light or too strong.

e) *Aircraft-net trapping.* Insects flying between 300 and 1000 m were sampled in a net mounted on a Cessna 172 aircraft. This trapping system was especially developed for this project by the Division of Entomology and the CSIRO Research Aircraft Facility. Flights were made for up to 3 h each evening between 9 and 16 February. As a cost-saving measure, aircraft operation was curtailed whenever the radar indicated that the density of insects above 300 m was so low that it was unlikely any captures would be made.

126

4) *Capture-recapture.* A small-scale capture-recapture experiment was undertaken, with four live-capture light-traps operated at localities about 400 m apart. The traps were sited in different crops and in a fallow field. *Heliothis* moths were marked with felt-tip pens, a unique mark being used for each day and each trapping site.

5) *Meteorological observations.* To assist in the interpretation of the observations of insect movement, measurements were made of the weather conditions at the field site. Surface temperature, humidity, and wind were recorded autographically. Upper winds were measured by tracking a pilot balloon with a theodolite approximately every 3 h during periods of radar operation. On two nights, upper temperatures between 300 and 1500 m were measured with a thermometer probe fitted to the aircraft.

Summary of results

Analysis of the observation data is not yet complete. Some of the following results are therefore of a preliminary nature.

Emigration. A dusk emigration flight was detected with the radar each evening, the number of insects immediately above the crops and at altitudes up to several hundred metres increasing markedly as night fell. Insect densities above crops were regularly sufficiently high for the radar screen to exhibit a "white-out". The emigration flight was also detected by visual observations against the western sky during twilight, when it could be seen that some, but not all, of the emigrants were *Heliothis*-sized moths.

High-altitude migration. The radar showed that insects reached heights of several hundred metres each night following the dusk take-off. The number of migrants at these heights was usually "moderate", and varied relatively little from night to night. This was in marked contrast to observations made at more southerly latitudes, where fewer insects fly on cold nights but very intense migrations sometimes occur when the weather is favourable.

The insects flew predominantly towards the west, towards which they were carried by the prevailing easterly winds. Migration often continued with little change in intensity until midnight, when a gradual decline in numbers usually commenced; this is again in contrast with migratory behaviour in temperate Australia, where the decline often commences much earlier and numbers remain high after midnight only when weather conditions are particularly favourable. Migration was occasionally interrupted early in the evening by major storm complexes which produced unfavourable weather that persisted for several hours. Concentration of the migrants by the local wind systems produced by these storms was observed with the radar.

Because migrant numbers were only moderate, catches of large insects in the kite and aircraft nets were small. The samples obtained indicated that both moths and grasshoppers were present at altitudes above 100 m, and that *Heliothis* was unlikely to have been the predominant species.

Low-altitude flights. The radar showed that insect numbers below about 50 m remained high for 2-3 hours after dusk, the radar screen exhibiting "white-out" for much of this period. Flight at these heights continued after midnight, but numbers were reduced. There was little difference between numbers over an irrigated crop and over an adjacent fallow field.

Observations with night vision devices indicated that the large insects were predominantly moths, and that they were moving downwind both over the crop and the fallow. Counts of insects passing through a vertical light beam indicated numbers over the fallow were similar to numbers over the crops. The moths were accompanied by very large numbers of small insects, and by predating bats. Night-vision-device observations made in the middle of the Emerald irrigation area and at its upwind boundary were essentially similar.

Samples obtained in the goal and vehicle nets and in the tower-mounted light trap confirmed that moths, including *Heliothis*, were moving at these altitudes. *Heliothis* moths were caught in vehicle-net transects through both a cotton crop and an adjacent fallow field, but were more numerous in cotton.

Light-trapping and capture-recapture. A small number of marked *Heliothis* moths were recaptured after one or two nights, mostly in the same trap that they had been captured in originally, but occasionally in a trap located a few hundred metres away in a different crop. A single marked moth was recaptured a distance of 5 km from its release point. These results show that both retention within the crop and movement between adjacent crops occurs. The light-trap located in the fallow field caught many fewer Heliothis than those in irrigated crops.

The number of *Heliothis* caught each night increased steadily during the first half of the fieldwork, as the expected February peak of *Heliothis* adults built up. After two weeks, however, numbers began to fall quite rapidly as the peak passed. Because the lower numbers made some of the observation techniques ineffective, the fieldwork was terminated a few days earlier than had originally been planned.

As well as *Heliothis*, the traps caught considerable numbers of two similarly sized species, *Eudesmeola lawsoni* and *Spodoptera litura*, and fair numbers of three larger hawkmoth species. The presence of these moths, which at times were more numerous than *Heliothis* and which are probably all migratory, has added to the difficulty of interpreting the visual and radar observations.

Meteorological observations. Weather conditions were found to be generally suitable for moth flight, including flight at altitudes of several hundred metres, throughout the night. The prevailing wind was easterly; this may have been an inland extension of the southeasterly trade wind airflow, perhaps strengthened by a sea-breeze effect. This wind provided good conditions for immigration into the Emerald irrigation area from intensive cropping regions along the coast. Major storm complexes were the main weather factor inhibiting migration; temperatures were generally well above the threshold required for flight, even late in the night.

Measurements of insect radar reflectivity. Measurements made with live insects confirmed that *Heliothis* has a maximum radar cross-section of about 1 cm^2, and that it is easily detectable by the CSIRO Entomological Radar in the 0.5-0.75 nautical mile (926-1389 m) range interval in which quantitative radar observations are made, provided it is oriented sideways-on to the radar beam.

Difficulties encountered

The main difficulty encountered was that *Heliothis* numbers throughout the Emerald irrigation area were much lower than normal for the time of year. The project was timed to coincide with the February peak of *Heliothis* adult numbers, but numbers during this peak were much lower than in previous years, and other species of moths outnumbered *Heliothis* at times. This resulted in low catch rates in the various types of trap, and uncertainty about the identity of the insects observed visually and with the radar.

Few other problems arose. All items of equipment worked effectively throughout the fieldwork, and observations ceased only during storms or when insect numbers had fallen to levels where the various techniques ceased to be effective.

Extent to which objectives achieved, and proposed publications.

The project established that *Heliothis* undertakes movements on a short-range, between-field scale by flying downwind a few metres above the crop canopy. Because of the low numbers present, it was not possible to establish whether *Heliothis* populations in the Emerald area undertake long-distance, high-altitude migrations, as some *Heliothis* species are known to do elsewhere. However, the observations provided valuable information on the nature of insect migration in the Australian tropics, and the meteorological factors affecting migration, and it is proposed that these results will be incorporated into a scientific publication.

Recommendations for further research

Further fieldwork is required to determine the extent of movement in *Heliothis* spp., both on the short-range (between-field) and long-range (between-region) scale. Capture-recapture, vehicle and goal netting, and visual observations with a light beam and night-vision goggles, all appear effective for the study of short-range, low altitude movement. Radar, combined with kite and/or aircraft netting, is the only technique available for the study of long-range, high-altitude migration. All techniques will be more effective if used when *Heliothis* moths are numerous, and when they outnumber other species of large migratory insects; this is particularly so for the methods used to study high-altitude movement. Timing fieldwork to coincide with high numbers of adults will require intensive monitoring of *Heliothis* populations, and the logistical and financial flexibility to undertake fieldwork at short notice. Sufficently high numbers are likely to be found only in a crop or natural host where *Heliothis* is not an economic pest, as control measures are likely to suppress populations to levels where most observation and sampling techniques are ineffective.