

## WHY IS HELIOTHIS A PROBLEM ?

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*INTRODUCTION*

Of the five species of *Heliothis* in Australia, only two, *Heliothis armigera* and *H. punctigera* are major economic pests. They are clearly the major pests of cotton in all production areas. My comments in this paper refer only to these two pest species.

To cotton growers the answer to the question posed in the title, "Why is *Heliothis* a problem ?", may seem quite obvious and simple. *Heliothis* are a problem because their larvae damage cotton plants, often feeding directly on fruiting structures, and potentially reducing yield. The high value of the crop and consequent low damage thresholds then impose a considerable cost for insecticidal control. Added to this cost is the potential cost of the development of insecticide resistance, particularly in populations of *H. armigera*, which has been dealt with by Neil Forrester (this volume). However these aspects of the *Heliothis* problem which directly affect growers are not my major focus here. I wish instead to discuss the contributions of

- i. intrinsic aspects of *Heliothis* biology and
- ii. the effects of a diverse cropping system

in promoting *Heliothis* as a major pest. Indeed the point I wish to emphasise is that it is the interaction of various physiological, behavioural and ecological attributes of *Heliothis* with the host succession provided by cropping systems which contributes most to their pest status. I will outline

briefly what we know of the biology of *Heliothis* and then summarise the major ecological and life history characteristics which contribute to their pest status and make them difficult both to control and to study.

#### WHAT DO WE KNOW?

The general biology of *Heliothis* is well studied but their population processes remain poorly understood. Both species are widely distributed in Australia. *H. punctigera* occurs throughout mainland Australia, including the semi-arid inland areas, and regularly reinvades Tasmania. *H. armigera* is more common along the east coast and in northern Australia and declines in abundance towards the south. Nevertheless *H. armigera* does extend inland to irrigated cropping areas and occurs in all cotton growing areas.

The rate of development from egg through larval and pupal stages to the adult is temperature dependent. Development is generally faster when temperatures are higher, so development times can vary both seasonally and geographically. For example while development from egg to reproductive adult may require 35-40 days in mid-summer in the Namoi, it may take 55-60 days during spring. In temperate areas, both species may complete 4-5 generations during the season depending on local weather conditions and the availability of suitable hosts, while at more tropical latitudes breeding may continue throughout the year, again provided suitable hosts are available.

*Heliothis* spp. are typical of opportunistic insect species. They have four major attributes which taken together

might be considered to constitute the *Heliothis* "strategy" for dealing with a particular environment. These intrinsic attributes are;

1. POLYPHAGY - wide host range
2. MOBILITY - capacity for both short and long range movement
3. HIGH FECUNDITY - giving the potential for rapid increase in numbers
4. DIAPAUSE - allowing adverse periods to be overcome and maintenance of permanent populations in temperate areas

I will discuss these attributes in turn to indicate their importance in the overall strategy and the current research relevant to each.

#### 1. POLYPHAGY

Both species of *Heliothis* are highly polyphagous, that is they are able to utilise a wide range of plants as hosts for larval growth and development. In all they have been recorded feeding on at least 160 plants from some 40 plant families, including virtually all cultivated crops and a diverse array of native plants. However these hosts are not equally suitable for larval development. There are differences in growth and survival of larvae on different plants due to nutritional or toxic factors and due to differences in the diversity or abundance of predators and parasites associated with particular hosts. Clearly a plant will be a suitable host and so contribute to population increase only if females will lay eggs on it (ie. they recognise it as an

oviposition site and it is not repellent to them) AND if larvae can survive and grow to maturity on it. Thus the use of a wide host range requires both physiological adaptations in the larvae to allow them to cope with diverse plant chemistry and behavioural flexibility in the adult females allowing them to accept a wide range of hosts as oviposition sites. While an individual larva may develop on only one host species, depending on the local diversity of plants, one generation of a local population may develop on a number of hosts simultaneously. More importantly for the population dynamics of the species, polyphagy allows *Heliothis* to breed continuously during climatically favourable periods by exploiting a succession of different hosts through the season (which our diverse cropping systems conveniently provide). In addition populations may be maintained in seemingly unsuitable areas since females have a high probability of locating a host which is at least marginally suitable for larvae. At present we know a little about how different hosts influence growth and development of *Heliothis* larvae, but further work is underway at University of Queensland, University of New England, Queensland DPI and in CSIRO to measure the effects of different crop hosts on larval growth and mortality and to identify the range of potential native hosts (weeds) on which populations may develop. Work is also underway on the behaviours involved in host selection by *Heliothis* females, to identify the important cues involved and possibly to determine ways by which the host selection system may be disrupted or used to advantage in novel control measures.

## 2. MOBILITY.

The second major attribute of *Heliothis* is their mobility as adults. Noctuid moths are well known for their ability to move long distances and *Heliothis* is no exception. At least three types of movement can be distinguished (Farrow and Daly pers. comm). Firstly, short range movement within or near the crop or other vegetation. This is often termed trivial movement and involves the activities of feeding, mating and selecting hosts. Secondly long-range movement at low levels, up to about 20m above the ground, where the insect can control its flight direction and possibly receive cues from the habitats over which it is flying. Such flights may be involved in movement between feeding, sheltering and oviposition sites and enable moths to move between adjacent crops. In some situations *Heliothis* are known to use one crop for adult feeding or shelter through the day and another for egg-laying, with a nightly movement between the two. These flights may however extend over 10-15 kilometres and so enable intercrop movement within regions.

The third class of movement is long-range movement in the upper air where the insects take advantage of strong wind systems to achieve downwind displacement over many kilometres. In this type of movement the insect has little control over its flight direction, nor over where it ends up. Radar studies by CSIRO have shown migratory movements of noctuids, including *Heliothis*, at heights up to 1000 metres but usually concentrated between 200-400m. These flights may carry moths over distances of 50-500 km. in a single night. Some documented examples include spring migrations of *H. punctigera* from south-east Australia to New

Zealand (2000 km.) and from the Riverina of N.S.W. into Tasmania, and movements of both species from coastal Queensland to Willis Island in the Coral Sea (500 km.).

Migrating moths take-off during a clearly defined period around dusk and may remain airborne for varying periods. The distance moved will depend on wind speed and the duration of the flight. The moths are unlikely to "select" where they come back to earth and trivial movements will be resumed in order to locate feeding and oviposition sites in the new habitat. In some noctuids there is a distinct, apparently obligate, phase of migratory behaviour (eg. the African armyworm) soon after emergence and before the insects are reproductively mature. For *Heliothis* we do not yet know whether moths which engage in long distance migration or extensive local movements are a particular sub-class of the population (eg. newly emerged, immature individuals), nor do we fully understand the cues involved in determining whether moths remain in the general area of emergence or move elsewhere. However, there is considerable evidence that a source of nectar (required for maximum reproduction) and attractive hostplants are important in holding moths in a local area. In the absence of such resources, where for example moths emerge into a mature or senescent crop, the population may engage in long-distance movement.

The importance of local or long-distance movement in the pest status of *Heliothis* is twofold. Firstly it allows moths to leave areas which are no longer suitable for reproduction and locate areas which are, thus promoting considerable intercrop movement within and between regions. Secondly, the potential for

long-range movement means that no cropping area can remain isolated from population processes occurring elsewhere. This is particularly relevant to the spread of insecticide resistance.

### 3. HIGH FECUNDITY

*Heliothis* females produce about 1000 eggs during their reproductive lifetime of 5-8 days. Fecundity is influenced by adult feeding, female size and indirectly by the host plant on which larvae developed. A female may lay up to 350 eggs in one night, most of them laid singly on different plants or plant parts. This high level of fecundity, coupled with the relatively rapid development of larvae, gives the potential for rapid rates of population increase when climatic conditions are favourable and suitable hosts are available. That is not to say all eggs survive to produce adults. Mortality over the life cycle is typically high, particularly for eggs and early instar larvae, due to climatic factors, predators and parasites. Evenso, only a small proportion of eggs need produce adults to maintain the size of a population and any small increase in this proportion can lead to a rapid increase.

### 4. DIAPAUSE

Diapause is a state of arrested development which may be induced by particular environmental conditions. Decreasing temperatures and photoperiods during autumn, which indicate the approach of an unfavourable period, are factors known to induce diapause in *Heliothis* pupae. Both species may enter diapause though there are discernible differences in the conditions which induce diapause and in the proportion of individuals which enter .

diapause under any conditions. In cooler regions such the Namoi Valley up to 95% of individuals may overwinter in diapause but this proportion decreases further north. Nevertheless there always appears to be a proportion of non-diapausing individuals capable of emerging in the late winter/ early spring should the weather be mild. In tropical regions breeding may continue year round. Further study is needed to determine the role of diapause in the dynamics of different regional populations.

The importance of diapause in the *Heliothis* "strategy" is that it provides a mechanism for surviving through periods when reproduction is not possible. As such diapause enables the species to maintain permanent populations in temperate regions which would otherwise require periodic immigration from more favourable areas.

##### 5. ROLE OF DIVERSIFIED CROPPING SYSTEMS.

The combination of features outlined above enable *Heliothis* to exploit host resources which occur as a mosaic of patches varying both spatially and temporally in their acceptability. Provided hosts are available somewhere within the range of adult movement breeding may occur season long. Consequently *Heliothis* are beautifully pre-adapted to exploit the diverse summer and winter cropping systems which have evolved in the major cotton growing areas. These systems provide suitable hosts from spring (lucerne, chickpea, rape, linseed, wheat, many weeds) through summer (cotton, maize, sunflower, sorghum) and into the autumn (cotton, sunflower, sorghum, lucerne, pigeon pea) and admirably suit a species with short generation time, the

ability to utilise many hosts and to move locally or between regions to locate them.

In the past *Heliothis* populations may well have existed by exploiting the extensive and reasonably predictable flush of weeds and a few crops during spring and then been maintained in small, isolated populations in favourable microhabitats or coastal regions during the summer. The typical pattern of population development may have had a major spring increase followed by widespread dispersal and the subsequent maintenance of small populations in localised favourable summer and overwintering habitats.

However the diversification of summer cropping and particularly the development of irrigation schemes in relatively arid areas has greatly altered the prospects for *Heliothis*, by providing a succession of suitable hosts. These alternative hosts are of prime importance for the dynamics of *Heliothis* on cotton since they undoubtedly act as the source of many of the moths which colonise cotton crops during the season. (Work aimed specifically at quantifying the contribution of particular crops to the recruits which appear in cotton is described elsewhere in this volume). In addition since *Heliothis* is rarely controlled on most of the alternative hosts they offer the possibility for rapid population buildup. While cotton itself produces some moths, the relative contribution of these to regional populations is not yet clear.

The importance of irrigated crops compared with dryland crops as sources of *Heliothis* varies from season to season depending on rainfall and temperature. While the former generally

support higher numbers of larvae and are more suitable for population increase the latter are much more extensive. Certainly in hot, dry seasons when reproduction on late season dryland hosts is limited much of the *Heliothis* population in areas like the Namoi will be concentrated in cotton crops and a substantial proportion of the next generation may be produced there. Moreover, since cotton is attractive and suitable for *Heliothis* development for a long period, it is exposed to immigrants from a number of potential sources during a season. In areas where irrigated cotton is surrounded by extensive areas of dryland crops cotton may in fact be the only attractive crop available at certain times of the year for moths emerging from under senescent crops of sunflower, sorghum, maize etc. and thus acts as a sink for immigrants from a huge area.

Although alternative hosts within a local area are undoubtedly important, immigration from other areas may also contribute substantially to the dynamics of *Heliothis* in a particular area. Thus adults which colonise cotton crops may have developed within the local area or alternatively may have migrated from crops many kilometres away. The problem is to quantify this contribution.

For researchers these factors mean that studies aimed at understanding and possibly predicting *Heliothis* numbers on cotton must be conducted on a regional basis considering all major hosts and movement between them as well as the potential for influxes from distant areas. Such studies are currently underway, both in the Namoi Valley (CSIRO) and on the Darling Downs (Qld. DPI).

Recent developments suggest that a further diversification of the cropping system is underway with the partial replacement of winter cereals by winter/early spring oilseeds (rape and linseed) and chickpeas, and the introduction of pigeon pea as an autumn crop replacing sorghum or sunflower. These changes greatly favour *Heliothis*. Chickpea is particularly suitable for larval growth, appears to harbour few natural enemies and will be attractive to adults emerging from diapause in September and October. Pigeon pea is also an excellent *Heliothis* host and as a late season crop could result in a major increase in the size of overwintering populations.

#### CONCLUSIONS.

As I have shown the pest status of *Heliothis* derives from the interaction between the behavioural and ecological features of these moths and the opportunities afforded by current cropping systems. I wish to leave you with three major points. Firstly cotton fields or entire cotton growing areas are not closed systems independent of the population processes occurring elsewhere. The dynamics of *Heliothis* in cotton is influenced by processes occurring in surrounding cropping systems and even other regions. Secondly research on *Heliothis* must proceed at the regional level and involve extensive cooperation between research groups. Thirdly, ecological research to improve *Heliothis* management, aims to do just that, MANAGE populations in order to minimise the damage caused, not to remove *Heliothis* from the scene totally.

