STUDIES OF THE ECOLOGY OF *HELIOTHIS* SPP. IN INLAND AUSTRALIA: WHAT RELEVANCE TO THE COTTON INDUSTRY?

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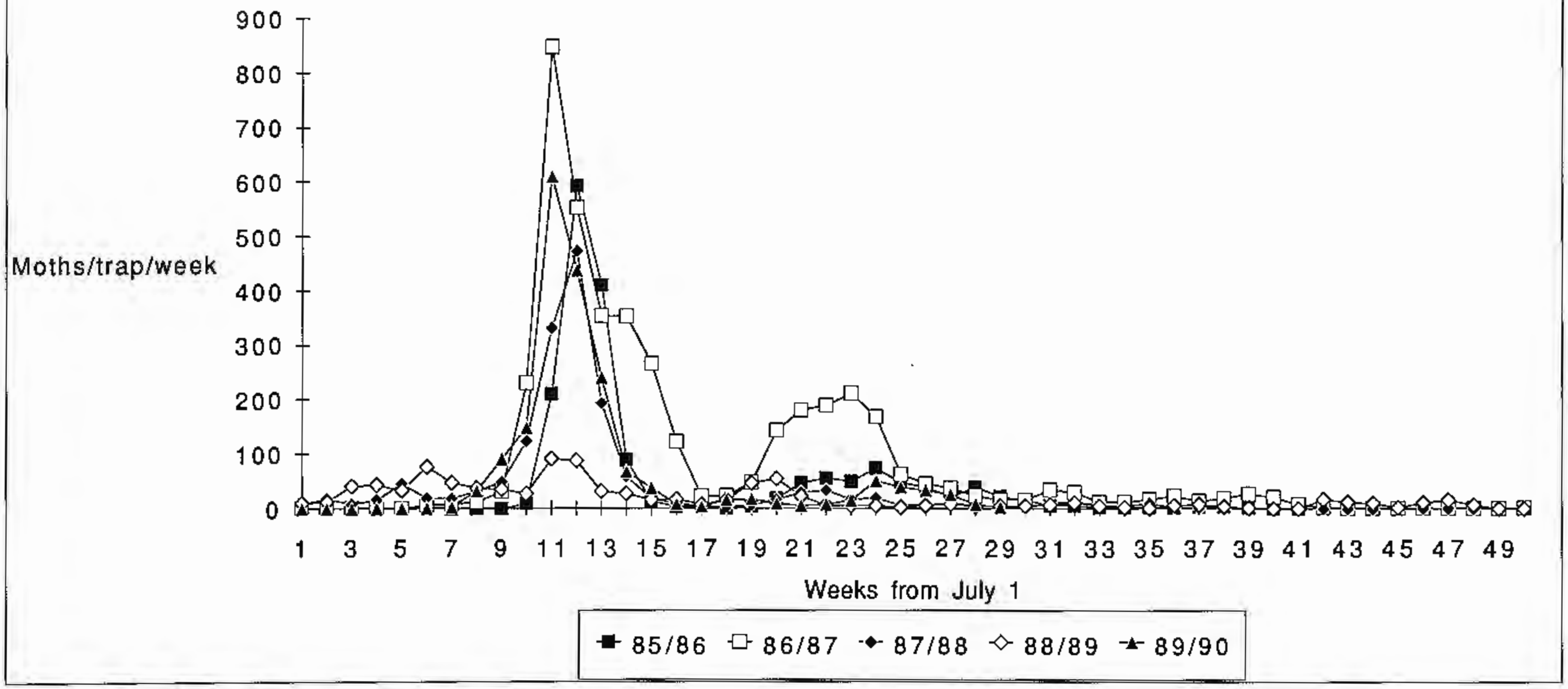
Introduction.

Heliothis spp. are clearly the major pests of Australian cotton and consequently there has been considerable research on their biology, ecology and control (Zalucki et al 1986). Most of this research has focused on *Heliothis* populations on particular crops within cropping areas. However, these species are not restricted to crops and exploit a wide range of non-cultivated host plants within and outside the cropping areas, in addition to their many cultivated hosts.

Our understanding of *Heliothis* populations has increased greatly over time, but there are several aspects of the population dynamics of ***H. punctigera*** in particular that are difficult to explain from a narrow perspective that includes only crops within cropping areas. One such problem is the origin of large numbers of moths that appear in eastern cropping areas in the spring (usually in the first half of September). This influx is characteristic of *H. punctigera* (Figure 1) and occurs almost synchronously over large areas of northern NSW and southern and central Queensland. In the Namoi/Gwydir these moths do not originate from local overwintering populations, since these are almost totally ***H. armigera*** (Fitt & Daly 1990). Moreover they appear before local emergence from diapause would be expected. Although substantial populations of *H. armigera* overwinter in the cotton areas, there is a suggestion from studies of resistance frequencies in early spring populations of *H. armigera* (Daly & Fitt 1990), that this species may also migrate into the cotton areas at that time. The origins of these spring populations have puzzled researchers for some time.

Previously *H. punctigera* was known to occur over large parts of inland Australia (Zalucki et al 1986, Farrow & McDonald 1988, Gregg et al 1989), though in these areas records were sparse and nothing was known of its ecology or seasonal abundance in these areas. By contrast, *H. armigera* was thought to be restricted

Figure 1. The seasonal pattern of H. punctigera catches in pheromone traps over the last 5 years at Myall Vale (week 11 commences Sept. 8).



largely to cropping areas and records outside them were rare. Over the last 3 years we have been studying the ecology of *Heliothis* spp. in inland areas of Queensland and NSW to investigate the possibility that these areas may be sources of the spring populations that appear in the cropping areas of northern NSW and southern Queensland.

The aims of our work were: (a) to more clearly define the distribution of the two major pest species of *Heliothis* in inland areas of Australia, (b) to determine the seasonal phenology of adults and larvae of each species and identify host plants and (c) to relate population peaks in inland areas to local weather patterns and (d) to relate these to peaks in eastern Australia by correlation with synoptic scale weather patterns that may link these areas via migration, leading to the possibility of predicting major influxes of *Heliothis* into cropping areas.

Why is it important to the cotton industry to know about the inland populations?

Research on the inland populations is of more than just academic interest. Knowledge of *Heliothis* dynamics outside the cropping areas is relevant to the cotton industry for at least two reasons.

1. Heliothis modelling and early season management strategies.

In order to provide cotton growers with predictions of the phenology and abundance of *Heliothis* on cotton during the growing season, CSIRO is constructing a series of simulation models called "HEAPS" (Hamilton & Fitt 1988, Dillon & Fitt 1990). These models need information on the likely size and timing of any influxes of moths coming into the cropping areas in order to simulate their numbers later in the season. One of the proposed regional management strategies for *Heliothis*, is the control of the first generation in order to reduce the size of populations later moving onto cotton (see Murray this proceedings). Information on the likelihood of major influxes from outside the region, that might nullify such attempts at regional management, is essential.

2. Insecticide Resistance Management.

The Insecticide Resistance Management Strategy has been in place now for 7 years. In most years the frequency of resistance in *H. armigera* in the Namoi Valley has shown a characteristic pattern (Forrester, this proceedings), being at low levels early in the season, increasing during and after the pyrethroid window in response to selection, then declining. The decline in resistance frequency which occurs from the end of one season to the start of the next has been a major factor in the continued efficacy of the pyrethroids and the success of the strategy. Why does resistance decline? The overwintering pupal populations of *H. armigera* in the Namoi/Gwydir have a high frequency of resistance (Daly & Fitt 1990), yet the first spring generation of this species (the first generation monitored on cotton is the *second* generation of the season) often has components with a low frequency of resistance (Daly & Fitt 1990). This, and the appearance of *H.armigera* before the expected emergence from diapause, suggests that some of the moths which initiate the first generation are immigrants from areas with low frequencies of resistance. Understanding the origin of these immigrant *H. armigera* and the dynamics of resistance in these source area(s) is thus highly relevant to the continued management of insecticide resistance.

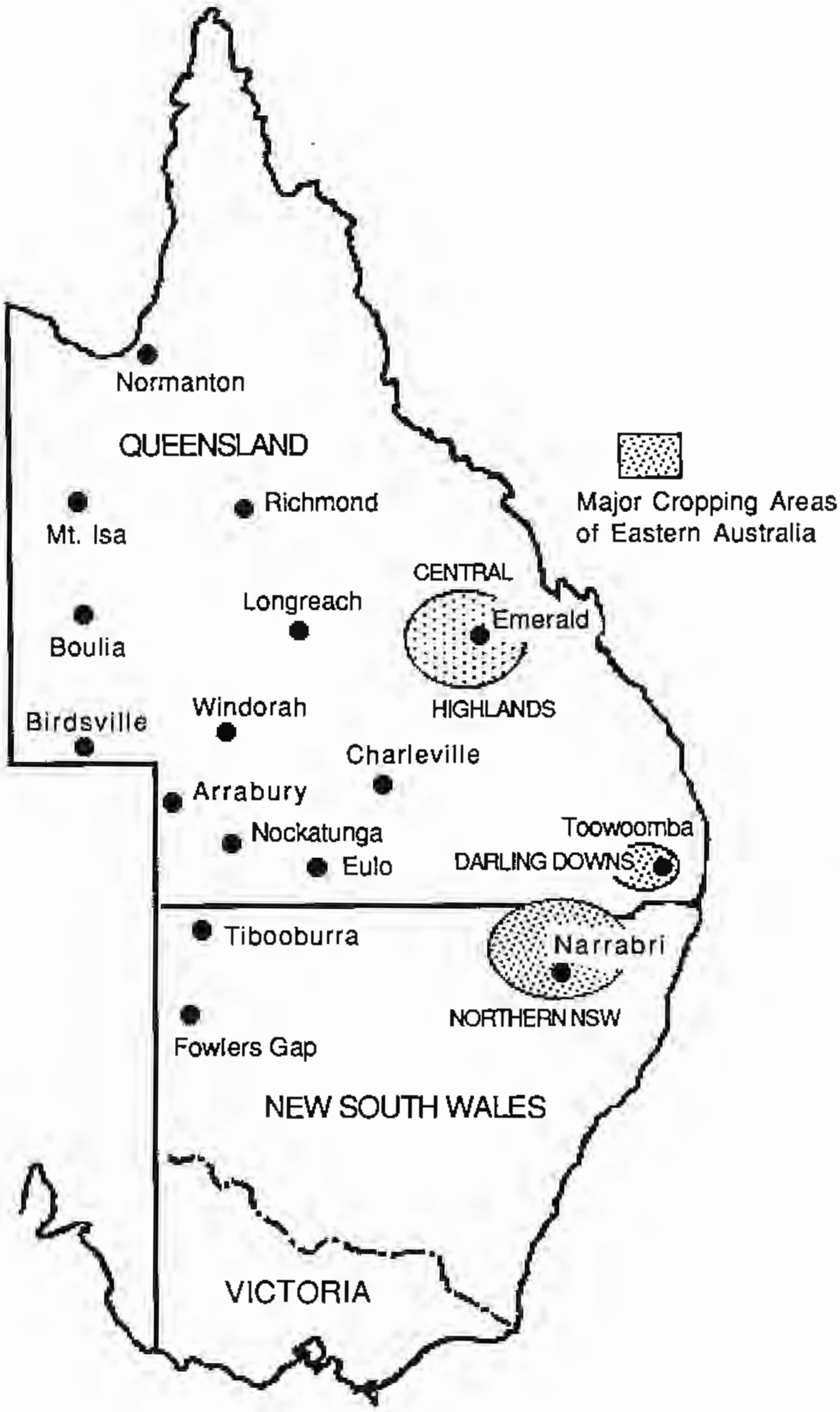
Results from Inland Research To Date.

Distribution and Abundance of Adults.

In July/August 1987 we established a network of pheromone traps and dataloggers at 13 sites throughout western NSW and Queensland to determine the distribution of *Heliothis* in inland areas (Figure 2). Each site is equipped with a pair of traps, one for each species of *Heliothis*, and a small datalogger which automatically records air and soil temperatures and soil moisture. Collaborators at each site clear and maintain the traps and change memory packs in the logger.

The trapping network has demonstrated the presence of adults of both *Heliothis* species throughout the study area. Traps at some sites, notably those throughout the Channel country (SW Queensland) and around Richmond (north-central Queensland) have caught moths in large numbers at times. The data show a consistent relationship between rainfall events during autumn, winter or spring and significant catches of one or both species 2-3 weeks later, whereas summer rain has not often been associated with catches. Figures 3 and 4 show the distributions of each *Heliothis* species as they were known in 1986 (Zalucki et al 1986) and the extent to which our project has extended these distributions, particularly that of *H. armigera,* which has now been recorded on several occasions as far west as Birdsville and in high numbers at Richmond and Longreach. The previous inland record was for Cunnamulla, but I.F.B. Common (who documented the record) did

Figure 2. Trap locations in inland NSW and Qld in relation to the major cropping areas of northern NSW and Qld.



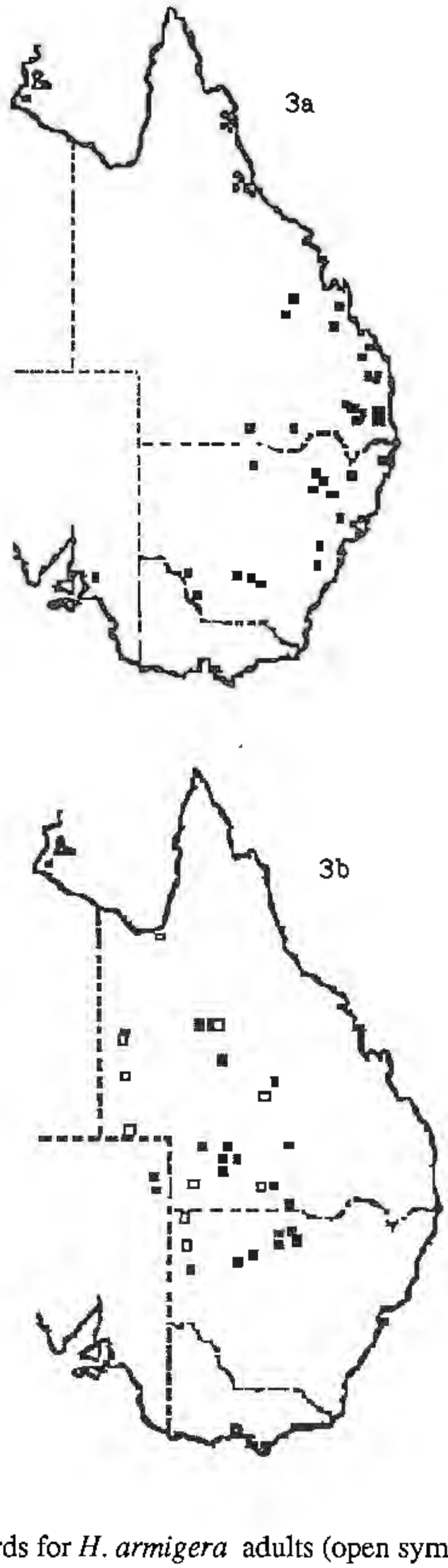


Figure 3. Distribution records for *H. armigera* adults (open symbols) and larvae (closed symbols) in eastern Australia. 3a. Records up to 1986 (Zalucki et al 1986). 3b. Records resulting from our research in inland areas.

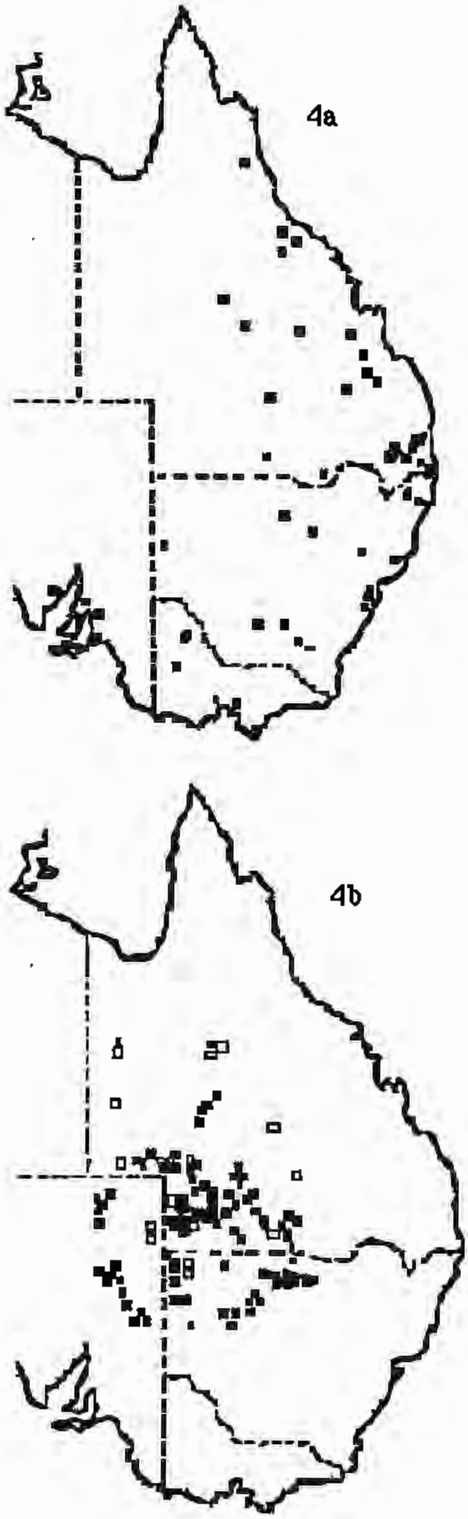


Figure 4. Distribution records for *H. punctigera* adults (open symbols) and larvae (closed symbols) in eastern Australia. 4a. Records up to 1986 (Zalucki et al 1986). 4b. Records resulting from our research in inland areas.

not consider it representative of breeding populations in that area. It is clear however, that the western distribution of both species now mirrors the extent of our trapping network. We have just obtained funding (from the Cotton Research Council, Australian Special Rural Research Council and the Oilseeds Research Council) which will allow us to intensify our trapping in western Queensland and to extend the network further westwards.

Host Plants and Larval Densities.

Over the last three years we have made 11 survey trips through different parts of the study area to record larval host plants and to estimate population densities during autumn, winter and spring. Sampling techniques include sweep netting and visual searches of plants for larvae and light trapping for adults. All larvae collected are transferred to artificial diet in the field and reared to adults for identification of species or any parasites. Plant specimens are also collected for identification by the QDPI Herbarium.

Surveys over the last two years have confirmed the distribution patterns shown by the adult trapping (Figures 3 and 4) and have revealed breeding populations over vast areas of inland Australia during mid-winter, when populations in the eastern cropping areas are in diapause. In late winter 1988, larval populations of predominantly *H. punctigera* were located extensively throughout NW NSW and the southern Channel country. During winter 1989, high densities of *Heliothis* larvae were present over vast areas of inland Queensland, north-eastern south Australia and far NW NSW, but particularly in "the Channel country" of SW Queensland. In that season we estimated a total population of about 200 billion *Heliothis* larvae in the Windorah-Eromanga region alone (an area of 90,000 square kilometres of which about 80% supported hosts). Most of these were *H. punctigera*, but about 2% were *H. armigera* (thats 4 billion *H. armigera*). These larvae pupated in late winter, emerged in early September and we have evidence that substantial numbers migrated into the cotton areas of northern NSW and Darling Downs around the 10-14 September (see Gregg et al 1990 for details). We have no estimates of the survival rate of these inland larvae, but even if we assume only 1.0% survival, this would still produce 2 billion moths.

Although SW Queensland appears to have been the most productive breeding area over the last 2 winters, this need not always be the case. It is possible that different areas will be major sources of moths in different seasons depending on the timing and extent of autumn rainfall.

To date we have identified about 50 plants in 6 plant families which are hosts of *Heliothis* spp., but new ones are found on each field trip. The most important, due to their abundance over wide areas, have been some of the everlasting daisies (Asteraceae), native goodenias (Goodeniaceae), some legumes (Fabaceae) and a number of Malvaceae (the same plant family as cotton). Most of these are native plants, though some introduced weeds have also been recorded as hosts in inland areas.

The abundance of these hosts is determined by the timing and extent of rainfall. They respond quickly to good conditions and the inland can change from barren plains to carpets of flowers within weeks. Areas of mulga and gidgee scrub, which characterise much of SW Queensland, and the floodplains of the main rivers in that area (Diamantina, Cooper Creek, Bulloo, Paroo) support diverse and prolific vegetation after good rains. Most of these plants dry off rapidly in the early spring, with the exception of those in some areas of the floodplains, and the *Heliothis* must leave to seek new breeding areas. When weather conditions are suitable these migrations can bring moths east to the cotton areas (Gregg et al 1990).

In order to quantify the extent of possible inland breeding areas and to monitor changes in its quality we are evaluating the use of satellite images produced by the NOAA satellite. The images, obtained monthly for all of eastern Australia, provide an index of vegetation "greenness" which we may be able to correlate with the suitability of an area for *Heliothis* breeding.

Resistance of inland H. armigera populations.

In collaboration with Dr. J. Daly (CSIRO Entomology, Canberra) we have begun using a resistance test on adults to determine the level of resistance in inland populations. In addition to its implications for resistance management in the cotton areas, discussed earlier, we hope to use measurements of resistance in the winter/spring populations as a marker for migration (Gregg et al 1990). Preliminary data from a small number of moths collected last spring suggests that the *H. armigera* produced in the Windorah/ Eromanga area were susceptible to pyrethroids, but further resistance testing of moths collected from a wider area is needed before any conclusions can be drawn.

So to date we have:

1. Demonstrated the presence of breeding populations of both species of *Heliothis* over large areas of inland Australia. These populations are predominantly *H. punctigera*, but *H. armigera* is also widespread, though at low density.

2. Greatly extended the recorded western range of *H. armigera*, with the limit now defined by the western edge of our trapping area.

3. Identified numerous wild host plants, of *H. punctigera* in particular, but also of *H. armigera*.

4. Recorded the presence of extensive inland populations of larvae after widespread inland rainfall and demonstrated in one year that some adults arising from these populations migrated into the cotton areas of northern NSW and SE Queensland in early spring.

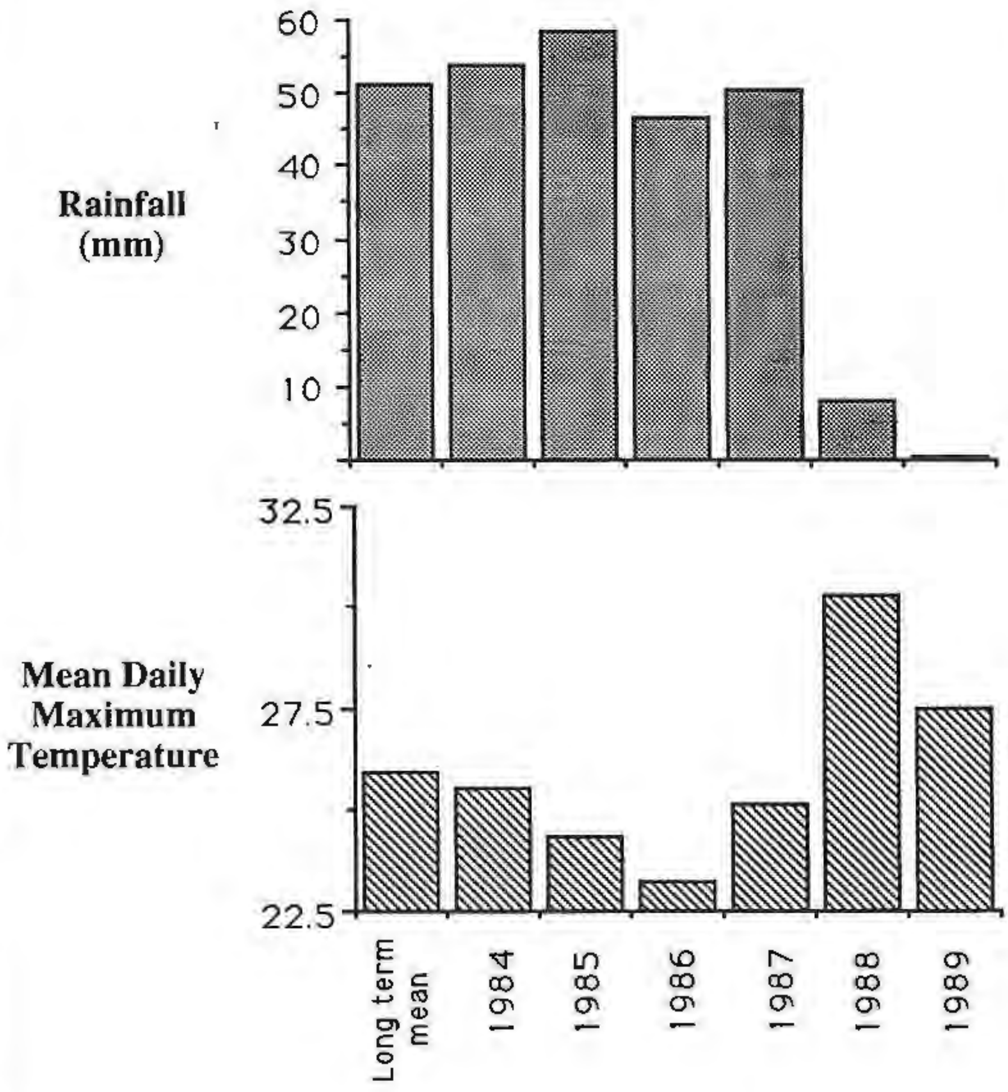
Why so few *Heliothis* during the last few cotton seasons?

Our observations of large winter breeding populations in the inland in the last 2 years and our suggestion that these provide the early spring peaks of adults in cropping areas seem at odds with the generally low abundance of *Heliothis* in the last 2 cotton seasons. But the story is not that simple; large winter populations in the inland do not translate directly into high densities on cotton during the summer because there is an intervening spring generation in the cropping areas on weeds and some crops, such as chickpea. Immigrants from the inland may be largely or partly responsible for establishing this first spring generation, but it is the fate of this generation, determined by *local* conditions, which defines the scope of population development during the remainder of the season.

This is clearly illustrated over the last 2 cropping seasons (1988/89, 1989/90). In 1988 large numbers of adults were present in early spring in the Namoi Valley and Darling Downs regions, but extremely dry and hot conditions during October, which was the hottest and second driest on record (26 years of data, Figure 5), decimated the first generation and populations did not recover for the remainder of the season (G.P. Fitt pers. obs, D.A.H. Murray & I. Titmarsh pers. comm.).

Similarly in 1989, October was dry, in fact the driest on record (Figure 5), and followed exceptionally dry months in August and September as well. In that spring there was only sparse growth of ephemeral host plants in northern NSW for

Figure 5. Rainfall and mean daily maximum temperatures for October at Myall Vale (1984-1989) and the long term mean (based on 26 years of data).



immigrant moths to use as host plants. Only very low densities of larvae were recorded on medics and other uncultivated hosts in the Namoi Valley and New England Tablelands and few of these probably survived due to the rapid drying off of vegetation in October. *H.punctigera* in particular remained at low densities for the remainder of the season on most crops (by contrast *H. punctigera* was extremely abundant on field pea crops in southern NSW and Victoria where seasonal conditions were more suitable).

Thus a "heavy" *H. punctigera* year may be the product of two interacting components: (i) large populations in the inland during late winter and (ii) suitable conditions in the spring for survival of the first local generation. *H. armigera* is a little different; its abundance will be partly influenced by the size of local overwintering populations and their subsequent breeding after emergence from diapause. However, we also believe the inland areas may be a source for this species in early spring and may have an influence on the dynamics of insecticide resistance. These observations show that in order to predict seasonal dynamics in cropping areas we need to understand both the origins and phenology of spring peaks of adults and the influence of local weather conditions on the establishment and survival of the first generation of larvae in September/October.

Future Plans.

To date our field surveys have been conducted whenever they could be accommodated with other research and teaching loads. However, we now have a technician located full-time from April to September in SW Queensland (at Charleville). He operates throughout western Queensland and conducts regular surveys for larvae, does more intensive adult trapping and collects data on the abundance and quality of vegetation. With recently expanded funding we plan to extend the trapping network and conduct more regular surveys trips as well. We have also initiated a project through the CSIRO Science Club "Double Helix" in which school children and their teachers are operating pheromone traps at 50 sites distributed all over Australia, but mostly east of Alice Springs, to better define the distribution and seasonal abundance of *Heliothis* spp.

Acknowledgements.

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References.

Daly, J.C. & Fitt, G.P. 1990. Resistance frequencies in overwintering pupae and the spring generation of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae): selective mortality and gene flow. *J. Econ. Entomol. 83 (in press)*

Dillon, M.L. & Fitt, G.P. 1990. HEAPS. A regional model of *Heliothis* population dynamics *(these proceedings).*

Farrow, R.A. & McDonald, G. 1988. Migration strategies and outbreaks of Noctuid pests in Australia. *Insect Science and its Application 8: 531-542.*

Fitt, G.P. & Daly, J.C. 1990. Abundance of overwintering pupae and the spring generation of *Helicoverpa* spp. (Lepidoptera: Noctuidae) in northern New South Wales, Australia: consequences for pest management. *Journal of Economic Entomology 83 (in press)*

Gregg, P., McDonald, G. & Bryceson, K.P. 1989. The occurrence of *Heliothis punctigera* Wallengren and *H. armigera* (Hubner) in inland Australia. *Journal of the Australian Entomological Society 28: 135-140*

Gregg, P., Fitt, G.P., Zalucki, M. & Twine, P. 1990. Evidence for spring migration of *Heliothis* spp. from inland Australia to cotton areas *(these proceedings).*

Hamilton G. & Fitt G.P. 1988. HEAPS, *Heliothis armigera* and *punctigera* simulation model. *Australian Cotton Conference, 1988, pp. 139-145.*

Zalucki, M.P., Daglish, G., Firempong, S. & Twine, P. 1986. The biology and ecology of *Heliothis armigera* (Hubner) and *H. punctigera* Wallengren (Lepidoptera: Noctuidae) in Australia: What do we know? *Australian Journal of Zoology 34: 779-814.*