Predicting Autumn diapause induction in *Helicoverpa* using long term average temperatures

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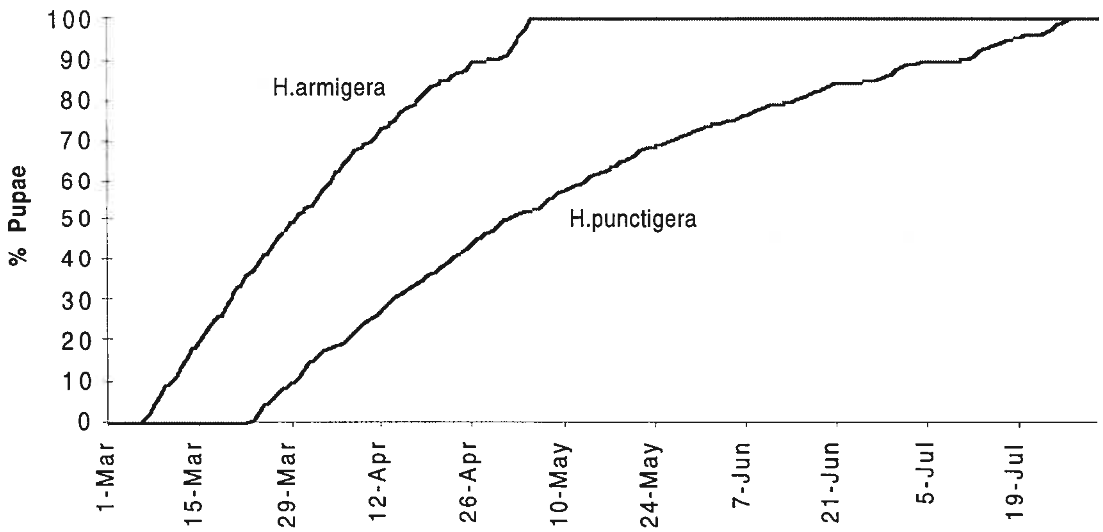
Introduction

Information on the likely timing of Autumn diapause induction in *Helicoverpa* spp. is useful for growers planning to cultivate cotton stubble for "pupae busting". Cultivation to control pupae is mandatory for INGARD cotton, and it is recommended for conventional cotton as part of the Australian Insecticide Resistance Management Strategy (Forrester and Bird 1996). The benefits of controlling *H. armigera* pupae in this way have been extensively published within the cotton industry (Slack-Smith *et al.* 1997, Fitt *et al.* 1993, Wilson 1993, Murray and Titmarsh 1990).

Pupal diapause in *Helicoverpa* has been extensively researched by Murray (1991). Diapause is induced when caterpillars are exposed to the falling temperatures and reduced day lengths of autumn. The effects of the interaction of daily temperatures and photoperiods are complex, and subsequently the incidence of diapause is quite variable. *H. armigera* and *H. punctigera* differ in their response, with *H. armigera* entering diapause more readily. In general induction into diapause is triggered when day lengths are decreasing and are below 12 hours of sunshine, and when daily maximum temperatures are falling and are less than 22°C.

Almost all over-wintering pupae in the Macquarie, Namoi and Gwydir Valleys are *H. armigera*, but both species enter diapause in Queensland. In the cotton growing regions of Southern Queensland and Northern NSW, pupae enter diapause from mid March through to the end of April and sometimes later. The proportion of new pupae that enter diapause rises rapidly over this period. Using long term average weather data, we have used the HEAPS model (Dillon and Fitt 1997) to predict the timing and proportion of new pupae entering diapause in several regions spanning the cotton growing valleys in Eastern Australia. Figure 1 plots the percentage of pupae entering diapause relative to the time of the year at Moree.

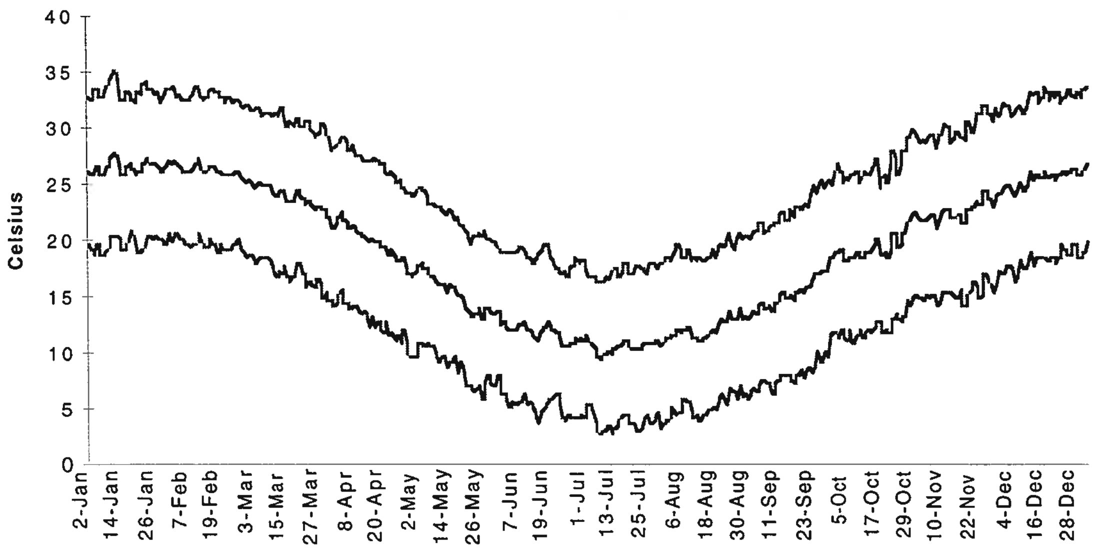
Figure 1: The predicted percentage of pupae entering diapause at Moree, NSW.



Predicting Autumn diapause induction

Daily temperature data was extracted from the Australian Meteorological Bureau database using MetAccess. All available temperature records were utilised: Emerald (1883-1992), Dalby (1873-1992), Moree (1879-1965), Narrabri (1891-1997) and Trangie (1898-1997). The average maximum temperature and the average minimum temperature for each day of the year was calculated, and used as input into the model. A typical pattern is illustrated in Figure 2.

Figure 2: Moree daily average Maximum, Mean and Minimum temperatures.



Egg lays were simulated for each week from the 1 February until over 90% of caterpillars developing into the pupal stage were entering diapause. For each weeks egg lay, HEAPS predicts the duration of larval development and the mean date at which pupation occurs. It then calculates the proportion of these pupae that are likely to enter diapause. HEAPS continues the simulation for the non-diapausing pupae, and predicts mean date at which these individuals will emerge as moths.

The models of diapause induction used in the simulations for each species is based on Murray's (1991, page 232) model derived from field cage studies at Toowoomba, Qld.

H.punctigera % diapause = 72.52 -6.63T + 0.044DT $r^2 = 0.78$

H.armigera % diapause = -6.19T + 0.095DT $r^2 = 0.77$

where D = Day number of the year, and T = a 5 day rolling mean of the average daily air screen temperature.

The results for each valley are presented in Tables 1 to 4 below.

Table 1: Central Queensland

Date of egg lay	Pupation	% Diapause	Non-Diapause emergence
1 February	21 February	0.0	5 March
8 February	25 February	0.0	10 March
15 February	7 March	2.1	19 March
22 February	12 March	15.7	25 March
1 March	22 March	42.0	5 April
8 March	29 March	57.8	15 April
15 March	6 April	74.4	23 April
22 March	15 April	90.9	18 May

Table 2: Macintyre

Date of egg lay	Pupation	% Diapause	Non-Diapause emergence
1 February	25 February	0.0	11 March
8 February	3 March	0.0	18 March
15 February	11 March	11.4	28 March
22 February	19 March	29.1	6 April
1 March	27 March	46.8	17 April
8 March	5 April	64.4	30 April
15 March	14 April	78.6	20 May
22 March	25 April	92.4	12 June

Table 3: Namoi

Date of egg lay	Pupation	% Diapause	Non-Diapause emergence
1 February	28 February	0.0	17 March
8 February	9 March	4.2	27 March
15 February	15 March	17.5	3 April
22 February	24 March	38.0	17 April
1 March	31 March	50.9	28 April
8 March	11 April	68.3	22 May
15 March	23 April	83.6	16 June
22 March	7 May	94.0	29 June

Table 4: Macquarie

Date of egg lay	Pupation	% Diapause	Non-Diapause emergence
1 February	23 February	0.0	13 March
8 February	3 March	0.0	25 March
15 February	14 March	17.6	6 April
22 February	21 March	31.9	13 April
1 March	2 April	51.0	7 May
8 March	11 April	68.8	25 May
15 March	1 May	79.5	23 June
22 March	12 May	91.1	4 July

Predicting Spring termination of diapause and the emergence of moths

The end of diapause and the emergence of moths is determined by local soil temperature conditions. Once the diapause is "broken", development of the pupa in the soil recommences. Because each individual pupae is exposed to a unique micro habitat of soil type, depth, moisture and temperature conditions, the time period during which the population of individuals end diapause and resume development can be quite broad. Overall *H. punctigera* tend to emerge 1 to 2 weeks before *H. armigera*, and females tend to emerge several days before males of the same species. Generally the peak emergence of moths from diapausing pupae occurs a number of weeks after the arrival of spring immigrants from outside the cotton growing regions. Moths emerging and arriving in the spring normally encounter an abundance of wild and cultivated host plants on which to lay their eggs. If local conditions are good and this first generation of moths is successful, the foundations are laid for a serious pest season ahead.

Models to predict the termination of diapause and likely emergence times were developed for *H. armigera* by Angus Wilson. These have been refined and validated by David Murray and are now incorporated into the HEAPS model. By using long term average temperature data for several cotton growing regions we have simulated the emergence pattern from diapausing pupae in each region and the results are summarised in Table 5.

Table 5: Spring emergence of moths from diapausing pupae

	1% emergence	50% emergence	99% emergence
Central Qld	14 August	3 September	6 October
Macintyre	28 September	23 October	23 November
Namoi	15 October	7 November	7 December
Macquarie	21 October	13 November	12 December

Discussion

The predictions presented in this paper are intended solely as a guide. They are still being refined, and simulations are planned for all Australian Cotton Growing regions. The final results will be incorporated into CottonLOGIC. Diapause induction and termination are complex aspects of Helicoverpa biology. It should be noted that temporal and spatial variation in temperature and rainfall will have a substantial influence on the timing of diapause. For any given region within a specific season, the actual timing and incidence of diapause may be quite different from the predictions presented above.

References

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