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Cotton Research and Development Corporation

Project Title: Factors influencing reproductive development, fecundity and longevity of Heliothis adults.

Project Number: CSE2C

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Background:

The development of population dynamics models of *Heliothis* populations in multicropping systems required information on reproductive development, longevity and lifetime fecundity of adult female *Heliothis* in order to simulate the daily input of white eggs to each simulation unit.

Studies with *H. armigera* and other species overseas have shown *Heliothis* spp. to be highly fecund. In the laboratory females may commence laying after a prereproductive period of 2-3 days and lay 1000-2000 eggs during their reproductive lifetime of 5-8 days. However only limited laboratory data was available for Australian *H. armigera* and little or no data is available for *H. punctigera*.. Potential fecundity in many insects is related to adult body size which in turn may be influenced by the quality of food consumed by the larvae. *Heliothis* develop on a range of cultivated and non-cultivated host plants which may vary considerably in their suitability for larval growth. Differences in weight of pupae produced on different crops have been recorded (Fitt unpub. data) which may influence potential fecundity and longevity. What was needed was a relative measure of the effects of host plant on reproductive performance to provide coefficients for the simulation models.

In addition we required data on the effects of seasonal climatic factors, particularly temperature and daylength on rate of reproductive maturation and longevity of both sexes and of egg production in females at different times of the season. No quantitative data was available on such effects.

Aims:

To measure the effect of biotic factors (host crop, body size) and abiotic factors (temperature, humidity) on reproductive development, fecundity and longevity of adult *Heliothis punctigera* and *H. armigera* for incorporation into simulation models of *Heliothis* population dynamics.

Research

This project covered three major areas of work focussed on the reproductive performance of adult *Heliothis*:

(i) the influence of seasonal climatic factors on reproductive development and performance of both *H. armigera* and *H.punctigera*

(ii) the effect of biotic factors, larval host plant and adult body size, on fecundity and longevity of *H. armigera*

(iii) the impact of multiple matings on reproductive performance in *H. armigera*

Influence of seasonal climatic factors. A major part of the work involved studies to measure reproductive maturation, daily and lifetime fecundity and longevity under varying seasonal conditions in the Namoi valley. The aim was to develop a comprehensive model of *Heliothis* reproduction able to accommodate varying effects of temperature and humidity. This was achieved by following the development of cohorts of newly emerged adults held in an outdoor insectary where they experienced natural extremes of temperature and humidity. During the 1988/89 season cohorts were completed at approximately monthly intervals from December to April, while in 1989/90 cohorts were done for September through to February. For each cohort we record (a) the mean age of first mating as a measure reproductive maturation, (b) daily fecundity of individual females and (c) longevity and dry weight (at death) of each female.

These studies showed the following:
(i) *H. punctigera* was always more fecund than *H. armigera,* even though *H. armigera* is consistently the larger species (Table 1)
(ii) Oviposition commenced at around 40 DD with peak oviposition occurred from 50-100 day degrees (using a base of 12°C) after emergence, followed by a rapid decline, with all oviposition completed by 160-180 DD.
(iii) There was a curvilinear relationship between lifetime fecundity and average day-degrees during the oviposition period, with fecundity increasing to a maximum when mean daily temperatures averaged 13 DD.
(iv) *H. armigera* was longer lived than *H. punctigera,* and for both species longevity showed a linear and negative relationship to mean day-degrees during the lifetime, probably as a result of a physiological trade-off between somatic maintenance and egg production..
(v) Both species showed a typical Type I age-specific mortality function with initially high survival followed by rapid mortality from about 150 DD (Fig.1)
(vi) The frequency of mating showed a sigmoid relationship with physiological age (Fig.2), with 50% of females mating by 35-40 DD after emergence.

Effect of larval host plant and adult body size on fecundity and longevity

To quantify the effects of host crop on size and fecundity samples of pupae were collected from naturally occurring populations under different crops. Lifetime fecundity, longevity and dry weight of each female was then measured under constant conditions in the laboratory. The aim of this work was to determine whether larval host plant influenced fecundity and other parameters, other than through its effect on body size. In both 1988/89 and 1989/90 data was obtained for moths from maize, chickpea and cotton. Further data was obtained for

moths from sorghum, chickpea and maize during the 1990/91 season, but this has not yet been analysed and is not reported here. The low abundance of *Heliothis* during the first two seasons made it extremely difficult to obtain sufficient pupae from other crops.

Moths from maize were the largest and most fecund , while those from cotton were the smallest and produced fewest eggs (Table 2). There was a significant positive linear relationship between lifetime fecundity and body size (indicated by dry weight at death). This result was achieved irrespective of host origin indicating there was no additional effect of host plant on fecundity other than that due to differential body size. Likewise a single linear model best described the relationship between longevity and body size for all host groups.

Impact of multiple matings on reproductive performance in *H. armigera*

In the field female *Heliothis* may mate from 1-6 times during their lifetime. In our experiments, where cohorts of females are mass mated with surplus males for 3 nights before being separated into individual containers, most mate once or twice. To determine whether multiple matings result in greater fertility or lifetime fecundity, we conducted a laboratory experiment in which females where allowed to mate a varying number of times. These experiments showed no significant effect of mating frequency on lifetime fecundity nor on fertility; 95-99% of eggs laid by singly mated females were fertile throughout their lifetime.

Modelling reproductive development of Heliothis.

From the experiments described above sub-models were developed for both *H. armigera* and *H. punctigera* to predict:

- daily egg production as a function of physiological age and daily temperature
- age-specific survivorship of adult females
- proportion of moths mated as a function of physiological age.

The sub-model of daily egg production for *H. armigera* was further extended to account for seasonal trends in certain parameters and to include the effect of body size and hence, larval nutrition. These sub-models describe simple age-specific life tables for adults and are being incorporated into the HEAPS population dynamics model.

Achievement of Objectives.

This project was successful in achieving all its major objectives and in producing a quantitative description of reproductive development and performance of *H. armigera* and *H.*

punctigera for incorporation into the HEAPS model. The sub-models of daily fecundity, survivorship and mating explain much of the variation in the data sets and will be adequate to predict reproductive parameters over much of the breeding season. However, some further work may be needed on maturation, mating and fecundity of early spring populations when temperature conditions approach the threshold for development. Field observations suggest some anomalies which are not well explained by studies so far.

Publications.

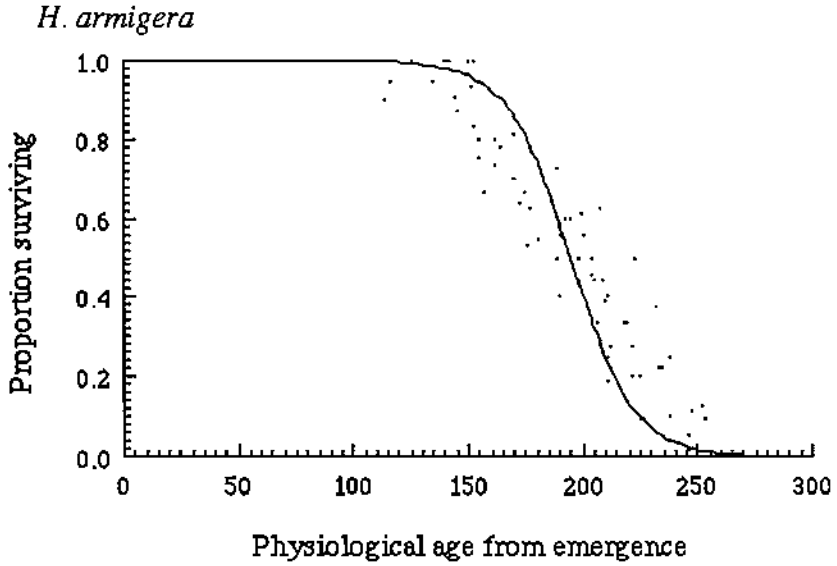
The bulk of the work conducted in this study has formed the basis of a Masters Thesis submitted by Mr. Spessa to the University of New England. The thesis is currently under examination. Formal publications will be developed from the thesis.

Table 1. Reproductive parameters for laboratory reared *H. armigera* and *H. punctigera* exposed to varying climatic conditions in the Namoi Valley.

Parameter	*H. armigera*	*H. punctigera*	Units
Average Lifetime fecundity	1255	1680	eggs/ female
Oviposition period	121	117	DD above 12
Time for 50% mortality	194	165	DD above 12
Time to 50% mating	41	35	DD above 12
Average dry weight	28	21	mg

Table 2. Reproductive parameters for *H. armigera* which developed naturally on different crop hosts or on artificial diet.

Larval diet	Adult dry weight (mg)	Lifetime fecundity	Oviposition period (DD°12)	Longevity (DD°12)
Artificial diet	27.2	1185	132	224
Maize	28.8	1250	142	229
Chickpea	27.4	1150	146	215
Cotton	21.4	838	129	178



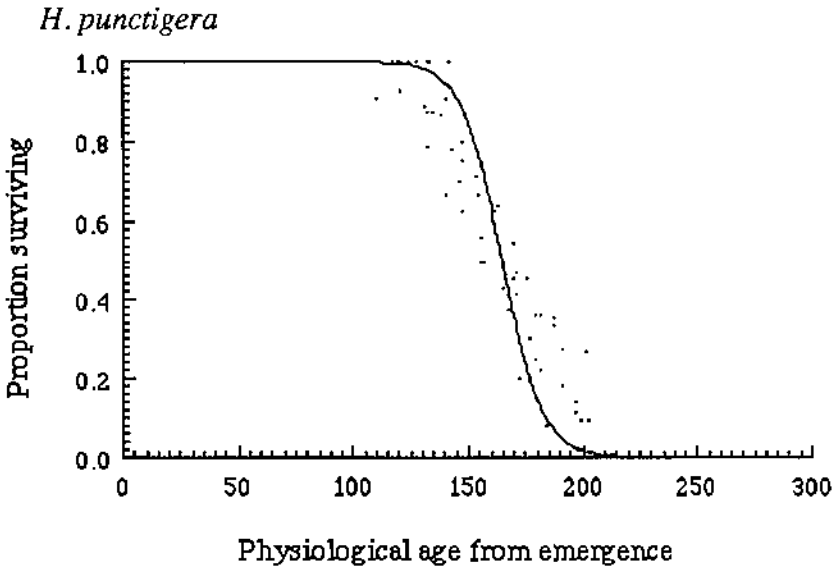


FIGURE 1. Observed proportion of early moths surviving and proportion of early mated moths surviving as a function of physiological age from emergence (DD^{o}_{12}).

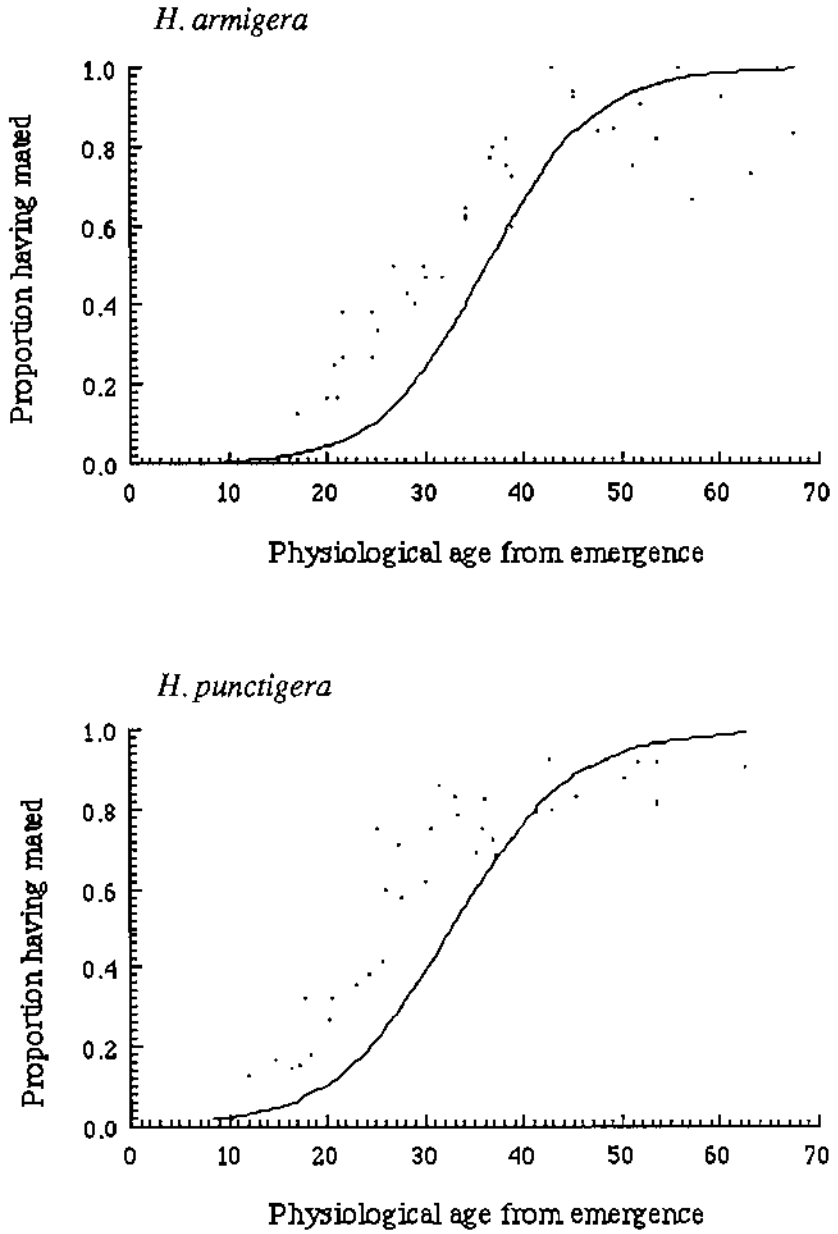


FIGURE 2. Observed proportion of moths mated and proportion of moths mated as a function of physiological age from emergence (DD^{o}_{12}).