TRAP CROPPING - A WAY OF MANAGING HELIOTHIS

Richard Sequeira
Farming Systems Institute, Queensland Department of Primary Industries, Locked Mail Bag 6, Emerald, Queensland, Australia 4720.

Introduction

Insecticide application to control heliothis on cotton is rapidly becoming a major production cost for field crops, particularly cotton, in central Queensland (CQ). Chemical protection of cotton crops is frequently required for more than 3/4 of the season. The intensive use of insecticides for heliothis control in cotton has led to an alarming rise in levels of resistance to many currently used insecticides (Fitt 1994, Gunning 1996). Insecticidal control of heliothis now costs many cotton growers in CQ in excess of $700/ha per season.

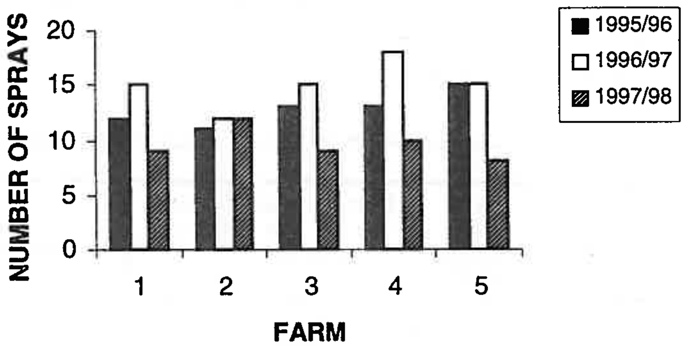

Fig. 1. Insecticide applications for heliothis control in the Emerald area: 1995/96 – 1997/98.

Fig. (1) shows the number of chemical insecticide sprays on cotton for heliothis control on five farms in the Emerald area over three consecutive seasons. Heliothis pressure varies from year to year. The 1996/97 growing season was a particularly difficult one in terms of pest pressure for Emerald cotton growers. Some crops required as many as eighteen sprays for barely adequate control of heliothis. This is a consequence of increasing insecticide resistance in heliothis and the generally higher abundance of the pest in CQ. Given the amounts of different insecticides used against heliothis and the rapid rise in resistance levels, it is not difficult to arrive at the conclusion that the viability of the cotton industry in CQ is under threat.

By the end of the 1996/97 cotton season, it had become apparent to Emerald cotton growers and industry workers that radical approaches and measures were urgently needed to attack the heliothis juggernaut. The ubiquitous pest status of heliothis, encompassing all cropping areas and most field crops in CQ, implies that any measures adopted must be strategic in nature and regional or area-wide in scope. After extensive consultation with growers and consultants, an area-wide heliothis management program for Emerald was developed and implemented at the beginning of the 1997/98 cotton season.

The following is an outline of the program, from inception to implementation. The outline addresses some of the practical considerations and difficulties encountered during the first year of implementation.

Area-wide management of heliothis

Concepts and background information

Development of a management program that specifically addressed the heliothis life cycle and pest problem in the Emerald environment required specific information on the ecology of the insect in the agro-ecosystem. The first step was to compile data on the population dynamics of heliothis in space and time. It was necessary to determine which crops produce moths, estimate moth density per unit area and location of crops in the area. The second step was to determine the pattern of migration between crops and crop zones (for example, between irrigated and rainfed areas). This information would then serve to evaluate the overall pattern, if any, of the pest problem and identify weak links in the system.

The nature of the problem

Surveys of pupae under various crops in CQ during the 1996-97 growing season revealed that irrigation areas, viz., Emerald, Dawson/Callide valley, produce large numbers of moths from August to March. Table (1) shows the abundance of heliothis pupae produced in relation to the cropping sequence in the Emerald area.

Table 1. Estimates of heliothis pupae per hectare under various crops in the Emerald irrigation area: 1996-97.

Crop	Oct 30	Nov 20	Dec 23	Jan 8	Jan 23	Feb 10	Mar 10	Apr 3
Chick pea	94000	42500						
Sorghum	0	48500	7250	9500			27500	
Mung bean		1000						
Sunflower			18000					
Cotton					125	16625		
Soya bean							7250	1833
Chick pea								7500
Peanut								0

A succession of crops were grown within the irrigation area, each contributing large numbers of moths to the ever-increasing heliothis juggernaut. The seasonal heliothis juggernaut began with a failed crop of chickpea within the irrigation area in late October. This chickpea crop was host to the offspring of the first spring generation of heliothis moths coming out of diapause within the irrigation area and moths migrating in from outlying rainfed areas. (NOTE: diapause does occur every year in CQ but is rarely 100%).

A number of sorghum crops within the irrigation area allowed the pest to build up in numbers. From sorghum, the pest moved on to mung bean and sunflower. Cotton began producing heliothis moths by early January. Cotton produces large numbers of moths from January through to March. Because cotton becomes relatively unattractive after the plant has cutout, the last one, or perhaps two generations of heliothis emerging from cotton are likely to look for alternate host plants.

The limited data available together with many anecdotal observations indicate that large numbers of moths emerging within the irrigation area migrate out to rainfed cropping areas and subsist on mid- to late-summer-planted crops, mainly sorghum and sunflower. This migration (summarised in Fig. 2 below) commences in the second half of stage III (around mid-February) and is facilitated by the close synchrony between emergence of heliothis from cotton and the presence of young and attractive grain crops in the surrounding rainfed cropping areas.

Rainfed winter chickpea crops serve as intermediary hosts, providing sustenance and overwintering or diapause sites to the survivors of the summer populations. A return migration to the irrigation area is observed in spring (August / September), at the start of the cotton season.

Components of the program and objectives

In view of the foregoing basic information, the management options that needed to be included in the program for the Emerald area were as follows:

1. **Within-crop management**. For long duration crops such as cotton, an effective Insecticide Resistance Management (IRM) strategy is necessary. A cotton IRM strategy has been in place for several years.
2. **Within-season management**. This option calls for the identification and management of all heliothis nursery crops within a defined area (the irrigation area in Emerald) during the growing season.
3. **Between-season management**. This option serves two main purposes. The first is to minimise the movement of heliothis populations across seasons by management of conduit crops such as winter chickpeas and late summer crops. The second purpose is to minimise the impact of the early spring heliothis populations. The tactics involved here are targeted pest control on conduit (nursery) crops and habitat manipulation.

The use of trap crops as a form of habitat manipulation was seen as the best option for the Emerald area in the initial stages of development of the area-wide management plan. Trap crops had to be positioned and attractive in August-September to soak up the incoming first generation of heliothis, and in February-March to prevent outward migration of the final generation of moths coming off cotton within the irrigation area.

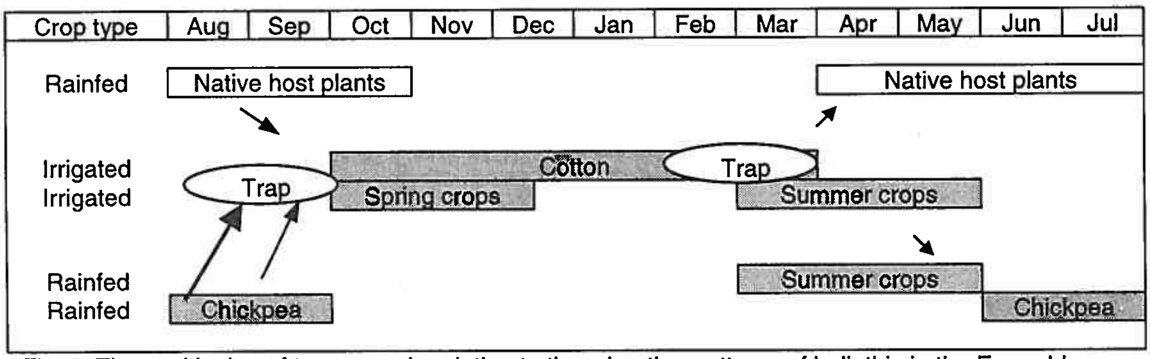

Fig. 2. The positioning of trap crops in relation to the migration patterns of heliothis in the Emerald area.

Figure (2) summarises the local migration pattern of heliothis and shows the positioning of the trap crops in relation to this pattern. The principle behind the summer trap crop is simply that if fewer moths are allowed to migrate out to survive on rainfed crops then fewer will return the following spring to re-infest the irrigation area.

The strategic objectives of the trap-cropping program were as follows:

1. Trap and destroy final generation of heliothis emerging from cotton so that
    - insecticide-resistant individuals (*Helicoverpa armigera*) can be eliminated,

- carry-over of the populations to late-summer crops is minimised, and
- migration out of the irrigation area is minimised.

2. Trap and destroy first spring generation so that
   - early-season build-up of the pest is delayed,
   - early-season insecticide usage is minimised, and
   - an early-season build-up of beneficial insects is promoted.

Trap crop layouts

The field layouts of trap crops for heliothis that are suitable for adoption on cotton farms can follow one of two basic designs. One is the patchwork design wherein every farming unit (farm or field) contains a patch of the trap crop. The patchwork design is applicable to cotton monoculture areas or areas where one or more substantial crop-free windows exist during the year. How big should a patch be? The answer to this question is unknown but is likely to depend on the size of the farming unit, economic considerations and effectiveness of the trap crop. The precise relationship between area and crop effectiveness is likely to be crop-specific.

The alternate trap crop layout is the intercropping or strip design. This layout may be more appropriate in diverse cropping systems or mixed farming areas where a number of different crops can be found growing at any given time. However, the applicability and effectiveness of this layout are yet to be examined.

Performance of trap crops in Emerald

A. *Winter chickpeas*

Of all the winter crops grown in the Emerald area, chickpea is perhaps the most attractive to heliothis. The crop becomes especially attractive after the onset of flowering. Emerald growers planted 1% of total farm area to chickpea trap crops in May 1997. For maximum attractiveness the crops had to be planted before the end of June. The trap crops began accumulating grubs in early August (Table 2). The density of grubs on the plants increased dramatically toward the end of August. The data in Table (2) and grower observations indicate that the Macareena variety of chickpea is much more attractive to heliothis than Amethyst. Over 85% of all larvae examined were found to be *H. armigera*.

Table 2. Abundance and distribution of heliothis larvae on chickpea trap crops in the Emerald area.

Variety	Date	Metres checked	Number and size of larvae collected				
			VS	S	M	L	Total
Amethyst	2/8/97	10 x 1	5	7	5	7	24
Amethyst	10/8/97	10 x 1	3	9	5	6	23
Macareena*	25/8/97	10 x 1	37	59	113	11	220
Amethyst*	26/8/97	10 x 1	12	42	67	12	133

* Data provided by Dr. David Murray, Queensland Department of Primary Industries, Toowoomba.

The crops were slashed at the end of August before many of the larger grubs on the plants could pupate, and the beds were cultivated thoroughly to destroy pupating grubs. The continuing presence of heliothis moths in early September seemed to indicate that the chickpea trap crops may have been destroyed prematurely. Heliothis moths terminate diapause and begin to emerge in early August, and continue to do so at least until the end of September. Therefore, if the spring trap crop is to be effective, it must extend well into September.

B. *Mid-summer pigeon pea*

Pigeon pea is one of the most attractive cultivated host plants for heliothis. The plant becomes attractive to heliothis only after the onset of flowering, which begins 60 – 65 days after planting. Flowering is indeterminate and the plant remains attractive as long as it continues to flower. Pigeon pea crops (1% of farm area) were planted at the start of the 1997/98 season, along with cotton. Table (3) below shows the refuge value of different cotton crops in the irrigation area in relation to pigeon pea during the season.

Cotton started producing heliothis pupae (moths) by the middle of December and continued to do so until the end of February (Table 3). Unsprayed cotton blocks, planted as refuge for Ingard cotton, produced large numbers of moths, thereby contributing significantly to the heliothis buildup in Stage III. Pigeon pea crops could be classified into two phenologically distinct groups. One group, consisting of the majority of crops in the area, was characterised by stunted crops that stopped growing and flowering by mid-December. These crops experienced hot and dry conditions during October and November. A few crops escaped early season stress as a result of frequent irrigation, which resulted in tall, continuously flowering crops. Both groups of pigeon pea crops produced large numbers of pupae, with the tall crops producing two to three times as many pupae as the other.

Table 3. Abundance and time of production of heliothis pupae on pigeon pea trap crops in relation to cotton in the Emerald area from April 1997 to March 1998.

CROP	Pupae per hectare (thousands)											
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Cotton												
Conventional	13	14							3	3	3	0
Ingard	0									4		
Unsprayed										56		
Rainfed											0	
Trap crops												
Pigeon pea (short)									41	27	51	22
Pigeon pea (tall)											174	675

The number of pupae produced by pigeon pea is evidence of the crop's ability to attract moths and eggs that would otherwise have been deposited on cotton. The timing of pupae production by pigeon pea indicates clearly that moths emerging from cotton at the end of February are being successfully lured into pigeon pea. Furthermore, the data indicate that the placement of the trap crops (February and March) is strategically correct.

Table 4. Abundance and distribution of heliothis larvae on pigeon pea trap crops in Emerald: 1997/98.

Crop type	Date	Area m^2	Number and instar of larvae collected				
			L_1 & L_2	L_3	L_4 & L_5	L_6	Total
Short	26/2/98	10 x 1	10	36	86	19	151
Tall	26/2/98	10 x 1	60	117	128	92	397
Short	2/3/98	10 x 1	0	20	45	11	76
Tall	2/3/98	10 x 1	0	19	94	31	144

The data in Table (4) lend further support to the foregoing discussion on the effectiveness of the pigeon pea trap crops. Large numbers of larvae of all instars can be found on the crops throughout February and early March. Note that very small (L_1) and small (L_2) larvae were not represented in the second sample collected in March (Table 4). This indicates that no new eggs were laid on pigeon pea after the end of February. By implication, the bulk of heliothis moths from that generation appear to have emerged from pupation and finished laying all their eggs prior to the end of February. Thus, the trap crops were able to soak up the bulk of the eggs laid by the final generation of moths from cotton.

Management of pigeon pea trap crops to destroy heliothis

Limited trials at the end of the 1996/97 season seemed to indicate that cultivation of standing pigeon pea crops was feasible and likely to be an effective means of destroying heliothis pupae. The rationale for planting pigeon pea along with cotton at the start of the 1997/98 season was that growers would be able to cultivate the trap crops from the onset of flowering to destroy pupae and thereby obtain insecticide-free control of heliothis. In reality, however, cultivation proved ineffective as the data in Table (5) below indicate. This was so partly because pupae tended to be found on the top of the ridge, beyond the reach of all cultivation equipment.

The data in Table (5) show that the tyne cultivator trial resulted in a 40% reduction in the number of moths emerging from the cultivated area relative to the uncultivated. In the Lilliston cultivator trial there was essentially no difference in the number of moths emerging from both treatments. Cultivation was also operationally difficult to manage because all growers could not do it at the same time, in the same way and with the same equipment across the management area.

Table 5. Effectiveness of cultivation in destroying heliothis pupae under pigeon pea.

Option & Indicator	Treatment	Date	Area (m^2)	Number of pupae/moths	
				Total	per m^2
Tyne cultivator					
Pupae collected	Uncultivated	6/2/98	10	196	19.6
Moths emerged	Uncultivated	16/2/98	27	181	6.7
Moths emerged	Cultivated	16/2/98	24	98	4.1
Lilliston cultivator					
Pupae collected	Uncultivated	20/2/98	10	128	12.8
Moths emerged	Uncultivated	7/3/98	30	39	1.3
Moths emerged	Cultivated	7/3/98	30	55	1.8

Conclusions

The data presented and discussion in the foregoing sections lead to the conclusion that the chickpea and pigeon pea trap crops were highly successful sinks for heliothis. However, lack of success in eliminating the heliothis on the pigeon pea crops stands out as the major weakness of the program. It is now apparent that elimination of heliothis on the trap crops must occur before the larvae become fully mature and leave the plant to pupate in the soil. In other words, heliothis control measures must be aimed at the larvae on the plant.

In-season trap cropping can be risky unless effective means of controlling the grubs on the trap crops all season long can be found. The risk arises from the fact that poorly managed trap crops become highly effective nursery crops. Therefore, the alternative is to restrict trap cropping to the beginning and end of the growing season.

Early-season trap cropping, if properly implemented, has the potential to yield immediate and tangible benefits to growers in terms of significantly lower heliothis pressure at least during the first half of the season. However, commercial chickpea crops could severely limit the effectiveness of their trap crop equivalents. To make the trap crops effective, the commercial crops must be either planted earlier or sprayed for heliothis control. Alternatively, a small portion of an early-sown commercial chickpea crop can be slashed to make it flower later so that it can serve as a trap crop for the balance of the commercial crop.

The development of an area-wide management program is an action learning process that is likely to be spread across several seasons. Successful trap cropping requires a very high level of co-operation between growers within the defined area. For economic reasons, a piece of land could be set aside for trap cropping on every farm within the management area. Unless the vast majority of growers in the area implement the program in its entirety, area-wide management is unlikely to yield benefits.

Where to from here?

The management plan for the 1998/99 season remains fundamentally unchanged. Chickpea trap crops are to be planted before the end of June and managed as discussed above.

Suggested modifications to the summer component are as follows:

- Pigeon pea crops are to be planted in late November so that flowering commences in late January / early February, populations of heliothis build up in February, and the risk of nursery crops producing heliothis during the season is minimised.
- Trap crops are to be sprayed in February and early March. The spray option of choice is virus (GEMSTAR®). The trap crops would require 3-4 sprays in quick succession (5-7 days apart) to expose larvae to the virus before they grow beyond the third-instar stage. The first spray would have to be applied shortly after a population of hatchlings and smalls (late first and second instars) is observed on the plants. The following sprays should target fresh egg lays as they occur.
- Trap crops are to be destroyed by the middle of March. Earlier destruction of the crops is an option if spraying is not possible or proves ineffective.

Literature cited

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