

## HELIOTHIS VIRUS: CAN IT RISE FROM THE ASHES OF "ELCAR"?

R.E. Teakle<sup>1</sup>, D.A.H. Murray<sup>2</sup>, R. Mensah<sup>3</sup>, C.J. Monsour<sup>1</sup>

<sup>1</sup>CRC for Tropical Pest Management, <sup>2</sup>QDPI, <sup>3</sup>NSW Agriculture

### SUMMARY

A *Heliothis* virus is set to make a come-back as an insecticide on cotton. Assessments (see reports, these Proceedings) indicated that the virus can perform well on conventional cotton, providing *Heliothis* pressure is not excessive.

Factors which now make the commercial outlook for the virus considerably more favourable now than for "Elcar" in the early '80s include:

- (i) a drastic reduction in effective alternative insecticides for *Helicoverpa armigera*,
- (ii) "Envirofeast"-enhanced predator effectiveness in IPM programmes, and
- (iii) availability of a new, improved virus formulation, "GemStar".

It is unclear whether the virus will have a role on transgenic cotton.

The virus works best as a component of IPM programmes where its compatibility with both "beneficials" and chemical insecticides can be exploited. It should not be viewed simply as a substitute for ineffective or inappropriate chemicals.

### INTRODUCTION

Biopesticides based on *Heliothis* nuclear polyhedrosis virus (NPV), one of the Baculovirus group, are notable for their potency, specificity and safety. The virus constitutes a natural mortality factor in *Heliothis* populations on cotton (Wilson and Greenup, 1977) and other crops. It has evolved to produce vast amounts of infectious virus per infected insect. This can be exploited by laboratory mass-production of the virus, and dissemination by the grower using conventional spray equipment.

This paper is designed to give background to reports on "GemStar" trials during the past two seasons. A brief history of its development as an insecticide in Australia is given in Table 1.

1978	* Heliothis virus formulation "Elcar" imported into Australia from the United States by Shell Australia. It was registered for use on cotton and grain sorghum, but could not compete with new synthetic pyrethroids.
1983	* Production of "Elcar" ceases in the US * Resistance to synthetic pyrethroids recorded in Queensland * Resistance management strategy on cotton implemented
1986	* Heliothis virus production by Biocontrol Ltd. (Warwick, Q.) aborted due to funding problems.
1988	* Production of recombinant Heliothis virus by CSIRO started (Christian and Oakshott, 1988).
1992	* Low-cost insect cell culture media developed in the United States.
1993-95	* Resistance to endosulfan, synthetic pyrethroids (Dowling, 1994) and thiodicarb in <i>H. armigera</i> escalated * Commercial development of "Envirofeast" by Rhone-Poulenc commenced. * Heliothis virus produced in cell culture at the University of Queensland. (Chakraborty <i>et al.</i> , 1995). * Heliothis virus, "GemStar" tested successfully in IPM on dryland and irrigated cotton at Dalby, Q. and Moree, NSW (see reports by D. Murray and R. Mensah). * GemStar registration on cotton in Australia initiated. * Medium-scale production of Heliothis virus in cell culture at the University of QLD.

**Table 1.** Chronology of factors associated with the development of Heliothis virus as an insecticide.

## HELIOTHIS VIRUS INSECTICIDES: PAST AND PRESENT

### ELCAR

A wettable powder formulation of a Heliothis NPV from *Helicoverpa zea*, "Elcar", showed early promise on cotton experimentally (Room, 1979), but attracted little interest in the marketplace. It suffered in comparison with the newly-available synthetic pyrethroids and other chemical insecticides and its credibility within IPM was never established.

Although there are similarities, it should be emphasised that the commercial environment into which "Elcar" was launched in 1978 was quite different from that

which exists in 1996, with the current escalating chemical insecticide resistance and residue problems, and scrutiny by environmental lobby groups. Furthermore, we now have a better understanding of the interactions of "Elcar" and *Helicoverpa armigera* and *H. punctigera* which affect the performance of the virus (Teakle, 1986a,b).

### **GEMSTAR**

A more recent *Heliothis* virus product, "GemStar", employs the same strain of virus as was in the ill-fated "Elcar" but has performed well in trials on cotton at Dalby, Q. and Moree, NSW. (see reports by Drs D. Murray and R. Mensah). The product was developed by *Biosys* Inc. and endorsed by the EPA in the United States, and registration in Australia is currently being sought.

### **IMPORTANT VIRUS CHARACTERISTICS**

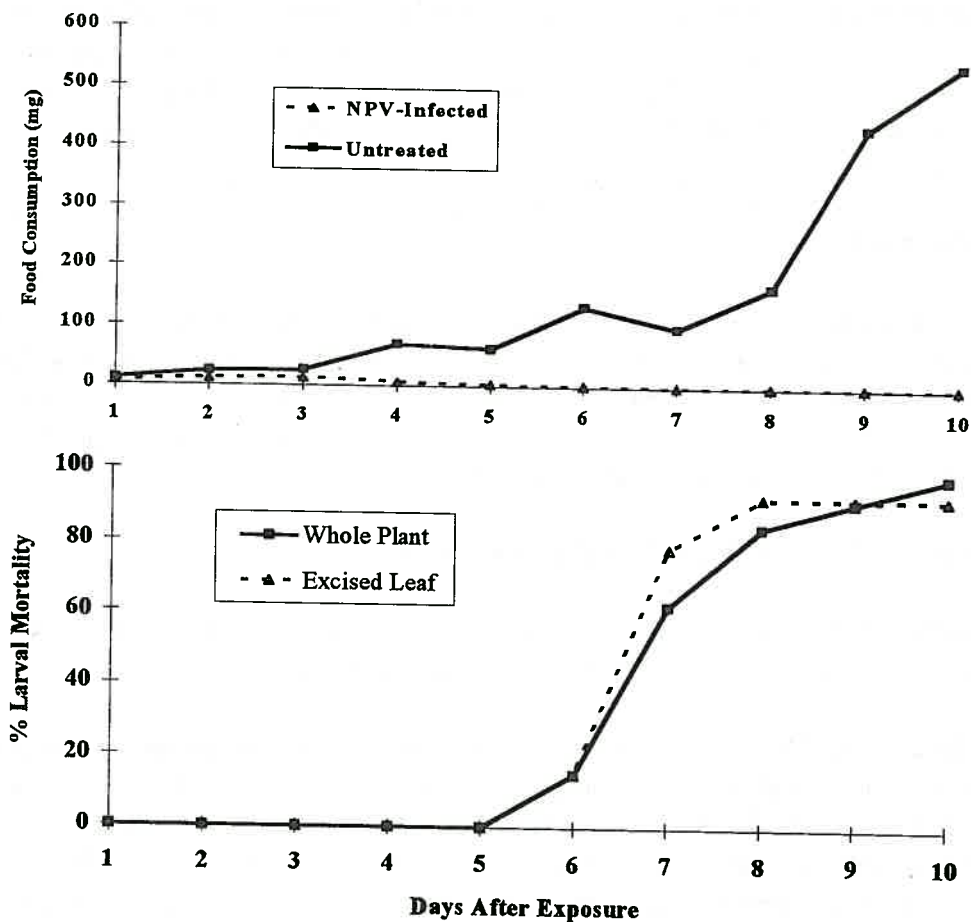
Some of the features of the virus which need to be understood in use against *Helicoverpa armigera* and *H. punctigera* are as follows:

**Specificity.** The virus is specific for *Helicoverpa/Heliothis* species. It is produced in live *Heliothis* larvae or cells in culture. It normally will not directly affect beneficial fauna on cotton. Parasites which have been developing in larvae for 3 or more days before infection will complete their development (Murray *et al.*, 1995). Predators may feed on infected insects and excrete active virus in their faeces (Cooper, 1981). It is safe for humans and other vertebrates.

**Compatibility with chemical insecticides.** Unlike many other biocontrol agents, the virus can be used in conjunction with synthetic insecticides and showed little evidence of interaction (antagonism or synergism) with them in mixtures with chemical insecticides (Teakle, 1991).

**Infectivity.** It infects only the larval stage of *Heliothis* when ingested with contaminated food. Feeding by the larvae continues unabated for about 3 days, but declines before the insect succumbs, usually after 6-7 days (Fig. 1). Timing is therefore critical to minimise crop damage. Before death, the larva tends to climb to the top of the plant where it disintegrates releasing massive amounts of virus, allowing the virus to spread between larvae within a population. This is aided by cannibalism in dense populations.

**Potency.** The virus in "GemStar" is highly potent, particularly for newly-hatched *Heliothis*. More virus is required to cause infection as larvae become older, and larvae become virtually immune to infection at about a week in age. When "GemStar" was applied experimentally to squaring cotton at the recommended rate, virtually all small larvae then applied to the foliage became infected. However, in



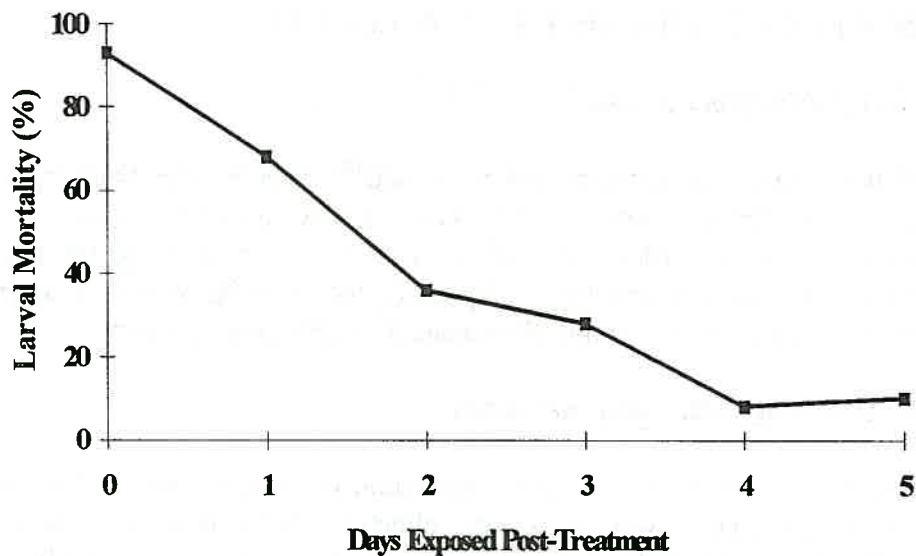
**Figure 1.** (Top) Food consumption of 2-day-old *H. armigera* larvae exposed to GemStar compared to untreated larvae.

(Bottom) Daily mortality of 3-d-old *H. armigera* larvae on squaring cotton plants treated with GemStar using excised leaf and whole plant bioassay methods.

the field where larvae are usually already established in reproductive structures, the rate of infection has averaged 50-60%. It is therefore essential that other forms of control are able to operate to complement the mortality due to the virus.

**Persistence.** The reduced mortality of larvae established in reproductive structures presumably results from degradation of the virus on the surface of the plant due to sunlight before larvae emerge. The half-life of virus activity on the cotton plant is in the order of 1-2 days (Fig. 2).

**Application.** The virus can be applied aerially or by ground-rig using conventional spray equipment.



**Figure 2.** Persistence of GemStar on squaring cotton. Residual activity was determined by daily infestation of exposed plants with 3-day-old *H. armigera* larvae.

**Resistance management.** The virus does not seem to be subject to resistance development in the field. Furthermore, there is little risk of cross-resistance with other insecticides owing to a unique pathological relationship with its host.

**Use in IPM context where possible.** It needs to be emphasised that Heliothis virus should not be viewed just as a novel insecticide to be substituted for ineffective or inappropriate chemical insecticides. It is most effectively used in the context of a season-long IPM program, as a Heliothis suppressant along with other biocontrol agents and/or adjuvants such as "Envirofeast" and "trap crops". Its use requires rigorous monitoring of pest levels and natural control fauna levels to ensure appropriate and timely use.

**Use against low or medium larval numbers.** Heliothis virus should not be relied on alone during periods of heavy Heliothis pressure. Effective contact insecticides would be more appropriate. The requirement for the virus to be ingested, plant growth dilution, sunlight inactivation and age-related tolerance to the virus will allow a proportion of the larvae to survive. Survival levels during heavy Heliothis pressure are likely to be unacceptable.

**Reduction in pesticide load on the environment.** The use of the virus to replace Bt early season should preserve beneficials on account of its specificity for Heliothis. Studies to establish this are needed. Heliothis virus may also serve as a partial substitute for conventional insecticides on conventional cotton in combinations which will alleviate the environmental drawbacks of the chemicals, in the same way that Bt has been employed (Forrester, 1992).

## ROLES OF HELIOTHIS VIRUS ON COTTON

### *Competition from Ingard<sup>TM</sup>*

Will the advent of transgenic cotton, Ingard<sup>TM</sup>, exclude "GemStar" from the marketplace as "Elcar" was by the synthetic pyrethroids? Possibly, but not so comprehensively. There will still be a need for effective applied insecticides for Heliiothis. The requirement will depend on the cost-effectiveness of Ingard<sup>TM</sup> cotton relative to that of conventionally managed or IPM-protected cotton.

### *Compatibility with transgenic cotton*

There would be little economic justification in using the virus while expression of the Bt toxin gene were at normal, effective levels. However, protection against Heliiothis is likely to be needed late-season when expression of the Bt toxin gene is reduced. The requirement for the virus to be ingested to work is likely to create problems in view of the antifeedant action of Bt toxin present.

Ways of suppressing the antifeedant response would need to be investigated, and there is evidence that "Envirofeast" is capable of doing this (Teakle, 1995). Nevertheless, use of the Heliiothis virus would be advantageous in view of the absence of cross-resistance with Bt and other insecticides, and its specificity and predator- and parasite-neutral status. This is particularly important in view of the expected reduced usage of broad-spectrum insecticides (see Tuart, 1995).

There have been no trials of the virus on Ingard<sup>TM</sup> cotton in Australia.

### *Conventional cotton*

The proportion of cotton grown using conventional control will ultimately depend on the cost of this relative to the cost of using Ingard<sup>TM</sup> cotton. Bt-resistance-management strategies currently advocated can involve the planting of conventional cotton requiring applied insecticides such as Heliiothis virus. These include:

(i) *Asynchronous planting.* With a narrow planting window for Ingard<sup>TM</sup> cotton before 15th November, growers, particularly of rain-grown cotton, whose planting times fall outside this period, will plant conventional cotton requiring applied Heliiothis control.

(ii) *Refugia, partial control of Heliiothis.* Bt resistance management currently is based on a requirement that farmers set aside a proportion of the cotton as refugia. This represents one third of the cotton if conventional management is exercised, or 10% if no control is exercised. With the first (one-third) option, partial control of Heliiothis using virus in refugia areas may be imposed to achieve the dual aim of acceptable cotton yield and generation of non-selected Heliiothis to mate with survivors from transgenic cotton.

Restrictions to planting of Ingard™ cotton in central Queensland because of Bt-resistance risks peculiar to this area are also proposed.

### ***Special cotton production***

Heliothis virus can be used to protect organic cotton or where naturally-dyed cottons are being produced. It is unlikely that such cottons will be genetically transformed as for Ingard™.

Should Bt resistance become established despite the insect management plan for Ingard™ cotton, Heliothis virus combined with other agents such as predators and parasites could be employed as a "safety net", in the same way as Bt (Forrester, 1992).

## **OPPORTUNITIES FOR IMPROVED PERFORMANCE**

***IPM programmes.*** Heliothis virus has the capacity to be the key mortality factor around which effective IPM programmes can be developed. A rain-fast "Envirofeast" formulation would complement the control exerted by the virus. The integration of these needs to be thoroughly investigated. Heliothis thresholds need to be flexible and modified to take account of types and numbers of "beneficials" present.

***Genetically manipulated virus.*** The insertion of toxin genes to shorten the response time of the virus in the insect is in progress within CSIRO (Christian and Oakeshott, 1991), and should improve virus performance.

***In vitro virus production.*** Cell-culture technology for producing "wild" or recombinant virus should allow greater control over product quality. This is now feasible with the development of low-cost (serum-free) media for virus production by cell culture (by fermentation) (Weiss *et al.*, 1994).

***Virus formulation.*** Formulations to protect the virus from sunlight and prolong its activity, and attract larvae to contaminated sites on the plants would improve the potential impact of the virus on the crop.

Progress on these aspects and the use of "trap crops" (eg. lucerne) for mirids and as a nursery for beneficials needs to be made on a broad front to achieve true "sustainability" in cotton pest management.

## **ACKNOWLEDGEMENTS**

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