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AREA-WIDE MANAGEMENT OF HELICOVERPA SPP. IN AN AUSTRALIAN MIXED CROPPING AGROECOSYSTEM

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Abstract

An area-wide management (AWM) strategy was developed and implemented in a mixed cropping agroecosystem on the Darling Downs, south Queensland, Australia, in response to a deteriorating situation with respect to the management of helicoverpa (*Helicoverpa* spp.). The cotton bollworm, *Helicoverpa armigera*, was the primary target for the AWM strategy because this species had developed resistance to most currently used insecticides and presented a dilemma for mid and late season management in cotton and grain crops. In this paper we outline the development of the AWM strategy first implemented on the Darling Downs in the 1998/99 season, and discuss its evolution, progress and impact on the farming system. The AWM strategy suggested tactics that aimed to reduce 1) the survival of over-wintering insecticide-resistant *H. armigera*, 2) the early-season build-up of helicoverpa on a regional/district scale, and 3) the mid-season population pressure on helicoverpa-susceptible crops. The participative research approach taken with AWM was enthusiastically supported by producers and associated agribusiness. Targeted research coupled with development and extension activities provided important support for the adoption of some tactics. AWM has facilitated the adoption of integrated pest management (IPM) approaches across the farming system. New technologies e.g. Bollgard®II, and the broader impacts of AWM/IPM are dramatically changing our agroecosystem, and it is vitally important that these changes are evaluated.

Introduction

Area-Wide Management (AWM) of helicoverpa (*Helicoverpa/Heliothis* spp.) is not a new concept. Knipling and Stadelbacher (1983) discussed the rationale of attacking populations during the first spring generation and this approach has been investigated since 1990 in the Mississippi Delta (Hardee *et al.* 1999). In Australia, Titmarsh (1992) was the first to advocate control of the first spring generation as a management approach on the Darling Downs, but it was Sequeira (2001) who acted in the 1997/98 season with a regional management program in the Emerald Irrigation Area. The driving force was the need to develop a pre-emptive resistance management strategy for the area to facilitate the introduction of Ingard® (Bt transgenic) cotton. Key components of this program were the use of early-season and late-season trap crops. It is this research that has been the catalyst for similar plans to deal with the helicoverpa crisis on the Darling Downs and elsewhere in Australia.

Under the AWM programs implemented in Australia, *Helicoverpa armigera* (Hübner) is the primary target because this species has developed resistance to most currently used insecticides and presents a dilemma for mid and late season management in cotton and grain crops. The ecology of *H. armigera* makes this species amenable to population manipulation as it is primarily generated locally and is not contributed to significantly by immigration events during the season. While large immigrations of *Helicoverpa punctigera* (Wallengren) from inland Australia may take place during late winter/spring in some years (Gregg *et al.* 1995), the tactics employed against *H. armigera* should also be valid against *H. punctigera*. The aim of AWM is an overall reduction in *H. armigera* population levels. In this paper we present the development and implementation of an AWM strategy on the Darling Downs in southern Queensland, Australia.

Until recently, *Helicoverpa* spp. were managed field by field or farm by farm, with little or no regard for what happened on neighbouring properties. There is now an appreciation that *Helicoverpa* spp. are pests of the farming system, and as such there is much to be gained by a regional or AWM approach.

Many *H. armigera* over-winter locally in our temperate cropping regions. *Helicoverpa* spp. develop on many weeds and most of our summer and winter crops, so there is potential for these to act as nurseries. The contribution of different crops to the *Helicoverpa* spp. problem is very seasonal and location dependent. The result of successive generations of *Helicoverpa* spp. developing on abundant host plants during spring and summer is unrelenting pest activity by late summer and autumn. Couple this high pest pressure with declining performance of ageing insecticide groups because of resistance, and a crisis situation has developed. The serious pest management problems of the 1997/98 season when pest control costs in cotton soared up to A$1000/ha was a further catalyst to take affirmative action.

Development and implementation of an AWM strategy

The Darling Downs AWM strategy was developed collaboratively by research and extension staff, cottongrowers, graingrowers and consultants (Figure 1). It considered the current knowledge of *Helicoverpa* spp. biology and ecology and interactions with the farming system. The strategy suggested tactics that aimed to reduce:

- the survival of over-wintering *H. armigera* pupae
- the early-season build-up of *Helicoverpa* spp.
- the mid-season population pressure on *Helicoverpa*-susceptible crops

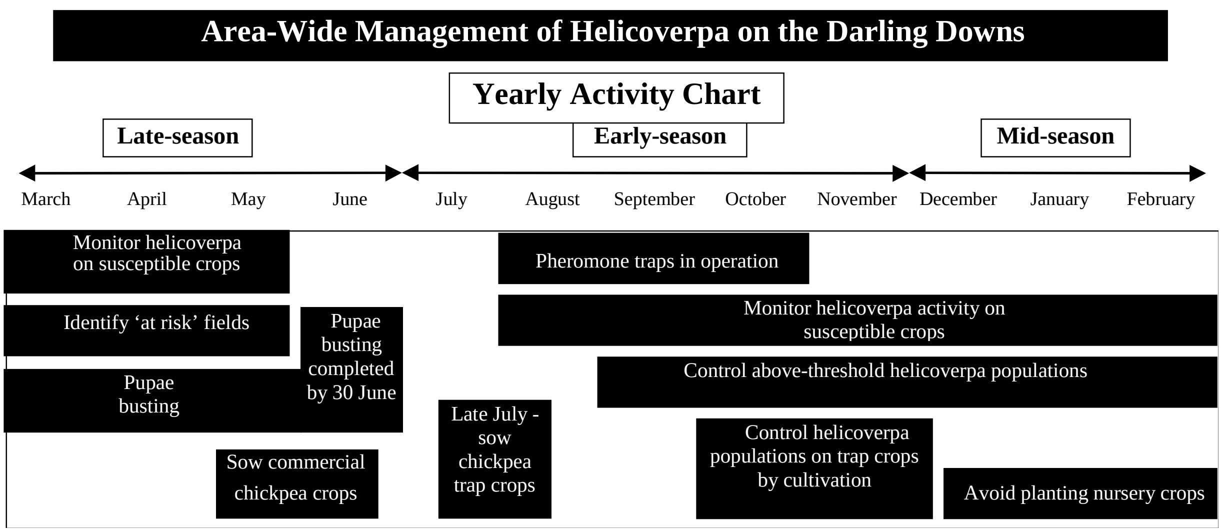

Figure 1. Yearly activity chart for AWM implementation on the Darling Downs.

The first two components target a bottleneck in the population dynamics of *H. armigera*. They recognise the contribution of over-wintering pupae to the spring population and insecticide-resistance carryover, and the role of spring hosts to act as nurseries for the first spring generation. The third component targets mid season generations on crop hosts and strives to improve pest management activities with less reliance on disruptive insecticide use (particularly synthetic pyrethroids).

The tactics

Pupae Busting

'Pupae busting' is a cultural practice that involves full soil disturbance and tillage to a depth of 10 cm. Identification of 'at risk' fields is a central issue for the pupae busting campaign. For the Darling Downs, the first over-wintering pupae are normally produced about mid-March. The precise commencement of production of over-wintering pupae will vary from year to year and be dependent on seasonal conditions. The *Diapause Watch* program provides up-to-date information on the incidence of over-wintering. Fields harvested before mid-March are unlikely to harbour over-wintering pupae, provided regrowth has not subsequently supported larvae. Any fields that are attractive to *Helicoverpa* spp. after mid-March are potential over-wintering sites. Pupae sampling should be used to detect over-wintering pupae, and is particularly important for planned no-till late season crops and double cropping opportunities. The recommended threshold for pupae busting action is one pupa per 10 m^2, but pupae busting is mandatory for transgenic Bt crops.

Pupae busting should be conducted as soon after harvest as possible, and preferably no later than 30 June. This time frame provides some flexibility to pupae bust before the desired cut-off date of late August should seasonal conditions hamper earlier pupae busting operations.

Spring population management

Improved management of commercial chickpea crops

It is important that winter crops such as chickpea do not act as nurseries for the first spring generation of *H. armigera*. For this reason, improved pest management guidelines should be followed. These guidelines include

- a planting window for the main commercial crop to avoid flowering during the normal spring emergence flights of *H. armigera* during October i.e. avoid sowing commercial chickpea crops after mid-June.
- consider row crop configuration to improve access for crop monitoring and ground rig spray operations.
- control above-threshold *Helicoverpa* spp. infestations on commercial crops within the limits of insecticide resistance and available registrations.
- determine species composition to aid pesticide choice decisions.
- destroy failed or abandoned crops by cultivation or herbicides immediately the decision to abandon has been made.
- control regrowth of harvested crops.

Use information from pheromone traps

Pheromone traps should be used to signal the arrival and/or emergence of the spring populations of *Helicoverpa* spp. Traps operate during August, September and October. As trap catches do not reflect species composition in egglays on crops, the information they provide should only be used as an alert for the commencement of more detailed sampling of crops for eggs and small larvae.

Sow a chickpea trap crop

Each property should sow an area (minimum 2 ha or 1% of cultivated area) of late-sown chickpea as trap crop to draw in locally produced *H. armigera* moths during the main spring emergence period (October) (Figure 2). These trap crops should be carefully monitored to time action against *Helicoverpa* spp. infestations. Trap crops should be destroyed by cultivation before pupation occurs, but spraying could be considered early in the life of the trap crop to prolong its useful contribution as a trap crop.

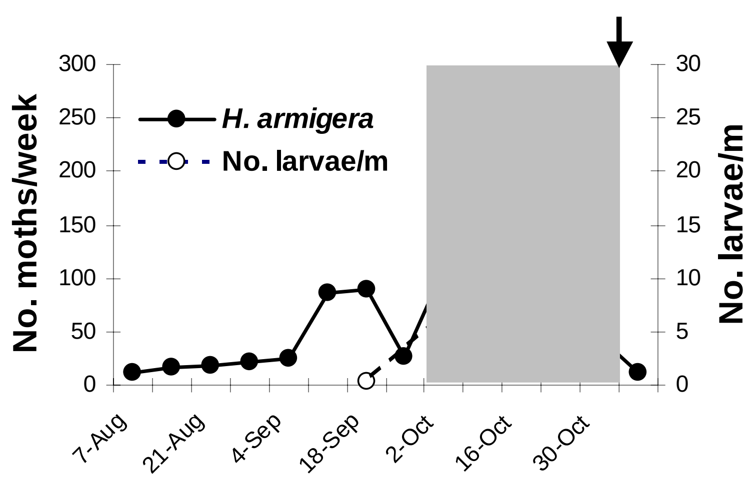

Figure 2. Spring abundance of *H. armigera* moths as indicated by pheromone trap catches, larval densities in trap crops and period of trap crop flowering (shaded area). Arrow indicates trap crop destruction by cultivation.

Promote the contribution of beneficial insects

Selective pesticides such as *Helicoverpa* nucleopolyhedrovirus (NPV) (Gemstar™ or Vivus®) should be recommended early season where appropriate. As natural enemies are not normally abundant on chickpea, beneficials should not be relied on to contribute greatly to *Helicoverpa* spp. egg and larval mortality. The use of disruptive insecticides (particularly pyrethroids and organophosphates) should be delayed in all crops for as long as possible. Where *Helicoverpa* spp. infestations are present and above threshold, they should be controlled within the limits of insecticide resistance and available registrations.

Mid-season population management

Insecticide management

Every effort should be made to conserve beneficials by using the most selective pesticide available. The use of disruptive insecticides (particularly pyrethroids and organophosphates) should be delayed in all crops for as long as possible. Where possible determine species composition to aid insecticide choice decisions. Where multiple sprays are used, coordinate rotations and alternate chemical groups. Adhere to the Insecticide Resistance Management Strategy (Johnson and Farrell 2004).

Crop checking

Helicoverpa spp. activity should be carefully monitored on all susceptible crops. Where *Helicoverpa* spp. infestations are present and above threshold, they should be controlled within the limits of insecticide resistance and available registrations. General advice is to manage crops so that they are not merely nurseries for *H. armigera*.

Implementation

This AWM strategy was first implemented in the 1998/99 season on two pilot study areas on the Darling Downs; the principally cotton-growing region between Cecil Plains and Brookstead and the principally dryland grain-growing region on the Jimbour flood plain. Each area involved approximately 100 growers who strongly supported the initiative. Implementation required a commitment from participants (growers, consultants) in each area. This strategy proposal was then taken to smaller group meetings within each of the study areas for discussion and to start fostering a sense of ownership of the project amongst the farmers who would be involved. The extension component of the project was central to the acceptance and uptake of the AWM concept, and the ongoing implementation of the key components. Targeted research provided important support for the adoption of some tactics.

For the first 3 years in which AWM was implemented and evaluated, growers met regularly in groups facilitated by both extension and research staff. These groups were a source of technical information for participants in the study, and provided an opportunity for growers to discuss and share experiences and knowledge with each other.

Discussion

Adoption of the basic AWM strategy has been widespread both within and beyond the pilot study areas, in both the grain and cotton industries. The direct impact of the tactics, such as spring trap cropping, pupae busting and improved helicoverpa management in grain crops, is difficult to quantify in terms of pest pressure or economic benefit. There have been dramatic changes in pest management practices within the agroecosystem over the past 5 years since the implementation of AWM, and these changes have made interpretation of quantitative evaluation extremely challenging. Some of these changes are discussed below.

Introduction of transgenic Bt cotton

Ingard® cotton containing the Cry 1Ac toxin was commercialised in Australia in 1996. Uptake peaked at 30% of the total cotton acreage and during the 2003/04 season delivered a 56% reduction in insecticide use compared to conventional cotton (Anon. 2004). While Ingard® cotton did not totally eliminate helicoverpa sprays, it provided a more solid platform on which to practice IPM. During its first year of commercial evaluation in Australia, Bollgard®II with Cry 1Ac and Cry 2Ab toxins led to further reductions (90%) of insecticide use (Anon. 2004).

Drought and low pest activity

During the last four years (2001-04) many areas of eastern Australia have encountered relatively dry conditions. The effect of low rainfall to reduce host plant availability (both wild and cultivated hosts) has probably contributed to the lower *H. armigera* activity during this time. Without detailed studies, it is impossible to partition the contribution of dry conditions to lower *H. armigera* activity. In contrast, some proponents of AWM are adamant it is their concerted efforts that have helped lower *H. armigera* population levels.

Registration of more selective insecticides

Reliance on older insecticide groups, particularly pyrethroids, carbamates and organophosphates, impose barriers to the adoption of IPM because of their disruption of natural enemies and risk of failure because of insecticide resistance. Some new, more selective insecticides (e.g. indoxacarb and spinosad) have now been registered in both cotton and grain crops (chickpea and pulses) and offer cost effective management of helicoverpa with reduced impact on natural enemies.

Widespread adoption of NPV

NPV was registered on grain sorghum for management of *H. armigera* in 1998. It is a cost effective, highly specific (minimal impact on parasites and predators), 'clean and safe' option that has no cross-resistance to current insecticide resistance mechanisms. NPV has completely displaced conventional synthetic insecticides in grain sorghum (Murray *et al.* 2001). In AWM programs, grain sorghum is now considered a summer trap crop for *H. armigera* and a refuge/nursery for beneficial insects (Scholz and Parker 2004). Registration of NPV on other grain crops will invariably take place soon.

Conservation of natural enemies

IPM has conservation of natural enemies as one of its founding principles. In support of existing natural enemies, the egg parasitoid *Trichogramma pretiosum* Riley was introduced from Western Australia in 1994 and has been released in southern Queensland since 1995 (Scholz *et al.* 2002). This parasitoid is now widely established on the Darling Downs and in many cases, mid to late season levels of helicoverpa egg parasitism on conventional cotton are sufficient to eliminate the need for insecticide intervention.

Attitudes have changed

In qualitative terms, the introduction of a 'new' approach to helicoverpa management has had a dramatic impact on attitude, and to some extent practice, of pest management in both the cotton and grains industries over the past few years (Ferguson *et al.* 2003). The change in attitude has significant benefits for these industries because it is driving a movement away from an unquestioning reliance on insecticides, towards the implementation of IPM. With the reduction in helicoverpa pressure expected as a result of continuing widespread adoption of AWM, it is probable that more regions will see the benefits from a change in approach to helicoverpa management.

The benefits of this change in approach to pest management will be seen in potential financial savings to growers both from reduced insecticide use, and/or reduced crop losses. There are substantial benefits to the health of individual growers and their families, as well as to the environment of reduced use of broad-spectrum insecticides. The perception of consumers, particularly towards the cotton industry, as a result of an ability to demonstrate a reduction in the use of pesticides, and particularly the 'old' chemistry is another area the industries can potentially exploit in marketing and promotion of products.

Future Issues

Further changes within the agroecosystem are likely in the years ahead. In its first full year of commercialisation for the 2004/05 season, 60-70% of the cotton acreage will be planted to Bollgard®II with an anticipated 85% reduction in insecticide sprays compared to conventional non-Bt cotton. It remains to be seen how the widespread adoption of Bollgard®II influences helicoverpa populations. Irrespective of changes in helicoverpa population dynamics, insecticide resistance management, including management of transgenic toxins, remains the most important threat posed by *H. armigera*. Sucking pests such as mirids and stinkbugs are now more prominent in a system with reduced insecticides, and it is important that these pests are managed in a sustainable way.

Conclusion

AWM is a movement that has captured large sections of industry and acted to focus attention on specific issues. While the implementation of *H. armigera* population management was the primary driver for the formation of AWM groups, the groups themselves have become significant in the information flow within the farming community. The groups are often the primary conduits for information flow from researchers to growers and vice versa, and between growers. In some regions, the focus of groups has broadened to consider other issues such as economics, water and nutrition. Across the cropping regions of Queensland and New South Wales, AWM groups are at the forefront of advancing knowledge and practice of IPM. New technologies e.g. Bollgard®II, and the broader impacts of AWM/IPM are dramatically changing our agroecosystem, and it is vitally important that these changes are evaluated and factored in to IPM/AWM programs of the future.

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