Predatory Arthropods in Australian Cotton Fields

P.C. Gregg[1], J.N. Stanley[2], M.L.Johnson[1] and M. Yee[1]
[1]Division of Agronomy & Soil Science, University of New England, Armidale NSW 2351, Australia
[2] CSIRO Entomology, PMB 3, Indooroopilly, Qld 4068, Australia

ABSTRACT

Over 50 species of predatory arthropods have been recorded in Australian cotton fields. The complex of generalist predators in Australian cotton has similarities and differences to those in other countries. It is dominated by coccinelids and other beetle species, bugs, ants and spiders. These predators attack Helicoverpa armigera and H. punctigera, the key pests of Australian cotton but also affect other pests such as mites and aphids and prey species with little economic impact suck as leafhoppers. Helicoverpa spp. are primary pests in Australian cotton. Under most pest management regimes predators do not maintain Helicoverpa numbers below current economic thresholds and predator population densities do not appear to be related to Helicoverpa abundance. In contrast, mites and aphids are usually secondary pests whose abundance is determines in part by the impact of pesticides on their natural enemies. This paper will review the predatory species involved, their abundance and seasonal phenology in cotton other crops and non-crop vegetation and the relatively limited data on their impact on Helicoverpa spp. The prospects for enhancing the role of predators of IPM will be discussed in relation to current trends in Australian cotton pest management.

Introduction

Cotton yields in Australia are high due to the mechanized and highly intensive nature of the industry and the substantial inputs of irrigation, pesticides and fertilizers. Insect pest management depends heavily on insecticides (Fitt, 1994) which are mainly directed against key pests, *Helicoverpa armigera* (Hübner) and *H. punctigera* (Wallengren). Important secondary pests include mites and aphids. Over 250 species of potentially predatory arthopods have been recorded in Australian cotton (Room, 1979; Zalucki *et al.*, 1986; Pyke and Brown, 1996) but only a few are likely to have a significant impact on pests. The most common taxa are shown in Table 1. This paper reviews the biology of some common predators, their abundance and seasonal phenology in cotton and other habitats and the limited data on their impact on *Helicoverpa* spp. The prospects of enhancing the role of predators are discussed relative to current trends in Australian cotton pest management.

Comparison of the predator complex in Australia with other regions

As in most cotton growing regions, predators in Australian cotton are mostly generalists (Stanley and Gregg, 1994). Prominent groups include the coccinellid beetles, spiders and predacious bugs (Geocoridae and Nabidae). In these respects the predator complex in Australia resembles those in the United States, China and Africa (King and Coleman 1989, van den Berg *et al.*, 1993). There are, however, some notable exceptions. For example, the emphasis given to ants as predators in Australia is much lower than in parts of the United States (McDaniel and Sterling, 1982) or Africa (van den Berg *et al.*, 1993). Though they are not uncommon in Australian cotton (Table 1) their role as predators is not understood and their abundance may be reduced by frequent irrigation. About 90% of Australian cotton is irrigated. Conversely, an endemic species considered significant in Australia is the red and blue beetle, Dicranolaius bellulus. It is one of the most abundant and conspicuous predators in cotton. Members of this family (Melyridae) are rarely accorded importance as predators of cotton insects in other countries.

Ecology and biology of some important predator groups

Most predators show strong seasonal patterns of abundance in cotton. Coccinellids are prominent in the early season, until peak flowering in January. Their numbers decline rapidly thereafter, even though aphids may be abundant in the late season (February-March). On the other hand, Geocoris and Orius spp. are most abundant late in the season. Dicranolaius bellulus is common throughout the season, but especially in mid-season. These different seasonal patterns reflect interactions between the phenology of the predators, the use of insecticides on cotton, and the availability of alternative habitats and prey (Stanley 1997). For example, comparisons between sprayed and unsprayed cotton suggest that the decline in coccinellids in mid season reflect the sensitivity of this group to the insecticides used at this time, notably synthetic pyrethroids. Coccinellid populations rarely recover from these sprays and their potential to control late season aphid outbreaks is not realized.

Cotton growing regions in Australia vary widely in alternative habitats for predators. In the Namoi Valley of New South Wales, there are few other summer crops apart from cotton. Winter cereals, especially wheat, are major early season habitats for predators which may move into seedling cotton when the wheat is harvested in November (Gurr *et al.*, 1998). Winter and spring weeds (like Rapistrum rugosum and Echium plantagineum) and pasture plants also support many predators at this time (Gurr *et al.*, 1998; Yee, 1998). These plants usually support large aphid populations which provide prey for coccinellids and other aphidophagous predators such as syrphids and neuropterans. In the summer the pastures and weeds may dry off. The concentration of predators in cotton and the widespread use of insecticides may lead to a regional depletion of predators. In other areas such as the Darling Downs of Queensland, the summer cropping system is more diverse and crops such as sunflower, lucerne and soybeans provide important alternative habitats which are rarely sprayed. Coccinella transversalis appears to track both aphid populations and plant phenology between these habitats (Yee, 1998). However predator populations in cotton usually remain low due to intensive insecticide use. These regions may have more severe Helicoverpa pressure, due to the availability of alternative hosts, leading to more extensive use of hard insecticides from earlier in the season.

There is little evidence for correlation between numbers of predators and Helicoverpa spp. in Australian cotton. Attempts to demonstrate density-dependent relationships have generally been unsuccessful. Spatial correlation analyses of suction samples showed that many predators were associated positively with the presence of the most abundant prey, cicadellids and thrips, but not with Helicoverpa spp. (Stanley, 1997). These results are similar to those recently obtained in US cotton by Ellington *et al.* (1997). There were, however, some negative correlations of Helicoverpa larvae with Orius and Geocoris spp. and salticid spiders, which could be interpreted as reduction in pest numbers by predation. Although they are key pests in cotton, Helicoverpa spp. are uncommon in crops relative to minor pests such as cicadellids, thrips and aphids, which represent abundant alternative prey (Figure 2).

This, together with the evidence concerning spatial correlations, suggests that Australian cotton predators are generalists whose population dynamics are influenced more by alternative prey than Helicoverpa spp.

Prey consumption studies

All of the predators listed in Table 1 consume substantial numbers of eggs under laboratory conditions, in small arenas such as Petri dishes (Room, 1979; Stanley, 1997) or single potted plants (Johnson *et al.*, 1998a). Some recent data for three species are shown in Figure 2. As with some US predators (Ables *et al.*, 1978), Helicoverpa egg consumption declined as the density of alternative prey (Aphis gossypii) increased, but the decline was statistically significant only for D. bellulus. Even when very high numbers of aphids were present, Helicoverpa eggs were still consumed. The results of Johnson *et al.* (1998a) also show that Helicoverpa egg density and the size of the plant affected consumption rates.

For Dicranolaius bellulus, evidence of Helicoverpa egg consumption from laboratory studies is somewhat conflicting. Stanley (1997) found that about 20 eggs were consumed per beetle in the first 24h, but this declined to about 5 per day, considerably lower than the rates found by Johnson *et al.* (1998a). Room (1979) found consumption rates of 7.9 eggs/day for D. bellulus after 5 days starvation, and 6.4 eggs/day for unstarved predators. Evidence from more realistic field conditions is limited. Stanley (1997), using 1m2 field cages, found consumption rates of up to 2.3 eggs/day for D. bellulus when Helicoverpa egg density was very high, but was unable to detect predation at more realistic egg densities, or when aphids were present. Field cage studies present many technical problems, some of which can be avoided by the use of immunological techniques (Sigsgaad, 1996). These techniques are being applied in Australia (Johnson *et al.*, 1998b), but results from field studies have not yet been reported.

Current and future roles for predators in IPM

Many attempts to grow cotton with few or no conventional insecticide applications have demonstrated that predators (and other beneficial insects) rarely control Helicoverpa spp. to levels below current Australian economic thresholds, which are about 2 larvae per metre of row (Fitt, 1994; Murray, 1994; Stanley, 1997). On the other hand, studies in which the effects of naturally occurring predators are combined with biopesticides (*Bt* and NPV) have indicated that yields close to those of conventionally treated cotton can be obtained in dryland situations (Murray *et al.*, 1996). In irrigated cotton, combinations of predators, *Bt*/NPV and 1-3 applications of conventional insecticides produced yields close to those obtained with 8 sprays of conventional insecticides (Mensah *et al.*, 1996). However, the contributions of predators to pest mortality, relative to other components of the IPM system, have not been quantified. This lack of information, together with the risk-averse approach of many Australian growers, has limited the application of these IPM schemes.

For secondary pests such as mites and aphids, there is abundant evidence that predators can control outbreaks if broad spectrum insecticides are avoided early in the season (Wilson *et al.*, 1996; Wilson *et al.*, in press). Most of the predators involved here are also predators of Helicoverpa spp., including many species listed in Table 1. Many Australian growers now consider the possibility of later mite resurgence when determining whether to apply early-season insecticides, and in their choice of chemicals.

While explicit recognition and exploitation of the role of beneficials in IPM is not widespread among Australian cotton growers at present, there are encouraging indications of change. Transgenic cotton expressing *Bt* toxin now comprises about 30% of the cotton crop, and has been associated with a reduction in broad-spectrum chemical use of around 50%. This reduction is most apparent in the early season, the time when benefits from predators are greatest. As might be expected from the lack of functional association between generalist predators and Helicoverpa spp., the numbers of predators in transgenic cotton do not seem to be reduced due to the shortage of Helicoverpa larvae (Fitt *et al.*, 1994). Reduced insecticide use not only promotes survival of the predators, but also their alternative prey. Thus, it is likely that the increasing use of transgenic cotton will favour an expanded role for predators in IPM.

Research aimed at manipulating populations of predators will also contribute to expanding their role. Food attractant sprays (Envirofeast®), timed according to predator/pest ratios, show considerable promise (Mensah and Khan, 1997). The benefits of such sprays may not be solely due to enhancing predator populations; there is evidence that they also deter Helicoverpa oviposition (Mensah, 1996). Habitat diversification to favour predators is another promising approach. Lucerne strips in cotton provide a refuge and early season source of predators (Mensah and Harris, 1996; Gurr *et al.*, 1998), and this technique has been combined with the use of Envirofeast® in experimental IPM systems (Mensah and Harris, 1996). Recent studies suggest that other habitats, both crops (Gurr *et al.*, 1998) and non-crops (Yee, 1998) might contribute to the maintenance and enhancement of predator populations. Pollen carried on the surface or in the digestive tracts of predators can be a useful indicator of the ways in which they utilize these habitats. Recent studies show that pollen from at least 35 different plants can be found on or in predators, indicating that they disperse regularly between habitats. Several weed species appear to be useful reservoirs for D. bellulus and C. transversalis (Yee, 1998). Understanding the ways in which these habitats can be manipulated for biological control of Helicoverpa spp. will be required for devising the best ways of exploiting naturally occurring predators in Australian cotton growing systems.

References

Ables, J.R., S.L. Jones and D.W. McCommans. (1978): Response of selected predatory species to different densities of *Aphis gossypii* and *Heliothis virescens* eggs. Enviromental Entomology. 7:402-404.

Ellington, J., M. Southward and T. Carrillo. (1997): Association among cotton arthropods. Environmental Entomology. 26:1004-1008.

Fitt, G.P. (1994): Cotton pest management. Part 3. An Australian perspective. Annual Review of Entomology. 34:17-52.

Fitt, G.P., C.L. Mares and D.J. Llewellyn. (1994): Field evaluation and potential ecological impact of transgenic cottons (*Gossypium hirsutum*) in Australia. Biocontrol Science and Technology. 4:535-548.

Gurr, G.M., S.D. Wratten, N.A. Irvin, Z. Hossain, L.R. Baggen, R.K. Mensah and P.W. Walker. (1998): Habitat manipulation in Australasia: recent biological control progress and prospects for adoption. Proc. Sixth Australasian Applied Ent. Res. Conf., Brisbane, 29 September - 2 October 1998, University of Queensland, Brisbane, Pp. 225-235.

Johnson, M.L., P. Gregg, J. Daly and I. Davies. (1998a): The role of beneficials – are some predators better than others at finding and consuming *Helicoverpa*? In: Proc. 9th Australian Cotton Conf. Australian Cotton Growers Research Association, Orange, NSW Australia.

Johnson, M.L, S. Trowell, J. Daly and P. Gregg. (1998b): Using immunodot assay to test which predators feed on *Helicoverpa armigera* (Hübner) in Australian cotton. In: Proc. 9th Australian Cotton Conf. Australian Cotton Growers Research Association, Wee Waa, NSW Australia.

King, E.G. and R.J. Coleman. (1989): Potential for biological control of *Heliothis* species. Annual Review of Entomology. 34:53-75.

McDaniel, S.G. and W.L. Sterling. (1982): Predation of *Heliothis virescens* (F.) eggs on cotton in east Texas. Environmental Entomology. 11:60-66.

Mensah, R.K. (1996): Suppression of *Helicoverpa* spp. (Lepidoptera: Noctuidae) oviposition by use of the natural enemy food supplement Envirofeast®. Australian Journal of Entomology. 35:323-329.

Mensah, R.K. and W. Harris. (1996): Envirofeast® IPM in cotton: Part 2. Use of lucerne as refugia for beneficial insects in cotton. In: Proc. 8th Australian Cotton Conf., Australian Cotton Growers Research Association, Wee Waa, NSW. Australia. Pp. 229-235.

Mensah, R.K., W. Harris and R. Teakle. (1996): Envirofeast® IPM in cotton: Part 3. Integration with nuclear polyhedrosis virus (NPV). In: Proc. 8th Australian Cotton Conf., Australian Cotton

Growers Research Association, Wee Waa, NSW. Australia. Pp. 237-246.

Mensah, R.K and M. Khan. (1997): Local density responses of predatory insects of *Helicoverpa* spp. to a newly developed food Envirofeast® in commercial cotton in Australia. International Journal of Pest Management. 43:221-225.

Murray, D. (1994): Organic cotton on the Darling Downs: a pest manager's nightmare. In: Proc. 7th Australian Cotton Conf., Australian Cotton Growers Research Association, Wee Waa, NSW. Australia. Pp. 195-198.

Murray, D., B. Ingram, R. Lloyd, J. Marshall, S. Thomson., B. Scholz and K. Rynne. (1996): Four years of IPM in raingrown cotton. In: Proc. 8th Australian Cotton Conf., Australian Cotton Growers Research Association, Wee Waa, NSW. Australia. Pp. 153-157.

Pyke, B.A. and E.H. Brown. (1996): The cotton pest and beneficial guide. Cotton Research and Development Corporation, Narrabri. 51 pp.

Room, P.M. (1979): Parasites and predators of *Heliothis* spp. (Lepidoptera: Noctuidae) in cotton in the Namoi Valley, New South Wales. Journal of the Australian Entomological Society. 18:223-228.

Sigsgaad, L. (1996) Serological analysis of predators of Helicoverpa armigera Hübner (Lepidoptera: Noctuidae) eggs in sorghum-pigeonpea intercropping at ICRISAT, India: a preliminary field study. In The Ecology of Agricultural Pests – Biochemical Approaches. W.O.C. Symondson and J.E. Liddell, (Ed). Chapman and Hall, London. Pp. 367-381.

Stanley, J.N. (1997): The seasonal abundance and impact of predatory arthropods on *Helicoverpa* species in Australian cotton fields. PhD thesis, University of New England, Armidale.

Stanley, J.N. and P.C. Gregg. (1994): *Helicoverpa* predators: do we know anything about them? In: Proc. 7th Australian Cotton Conf., Australian Cotton Growers Research Association, Wee Waa, NSW. Australia. Pp. 45-50.

Wilson, L.J., L.R. Bauer and G.H. Walter. (1996): 'Phytophagous' thrips are facultative predators of twospotted mites (Acari: Tetranychidae) on cotton in Australia. Bulletin of Entomological Research. 86:297-305.

Wilson, L.J., L.R. Bauer and D.A. Lally. (in press) Effects of early season insecticide use on predators and outbreaks of spider mites (Acari: Tetranychidae) in cotton. Bulletin of Entomological Research 88:477-488.

van den Berg, H., M.J.H. Cock, G.I. Oduor and E.K. Onsongo. (1993): Incidence of *Helicoverpa armigera* and its natural enemies on smallholder crops in Kenya. Bulletin of Entomological Research. 83:321-328.

Yee, M. (1998): Identifying potential habitats of predators of *Helicoverpa* spp. in two cotton growing regions. B.Sc. (Hons) thesis, University of New England, Armidale.

Zalucki, M.P., G. Daglish, S. Firempong and P. Twine. (1986): The biology and ecology of *Heliothis armigera* (Hübner) and *H. punctigera* Wallengren in Australia: what do we know? Australian Journal of Zoology. 34:779-814.

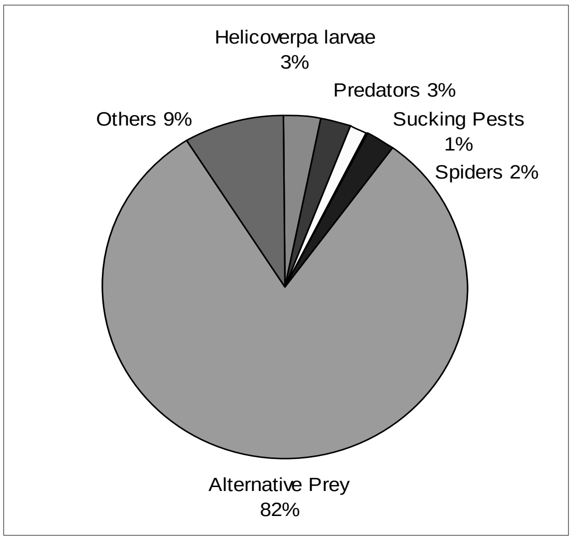
Table 1. Numbers of predators collected by suction sampling from three cotton fields over two seasons in northern New South Wales. Starred species are also phytophagous; *C. liebknechti* and *C. dilutus* are pests as well as predators.

Predator	Order: Family	Mature predators		Immature predators	
		Rank	Number	Rank	Number
Campylomma liebknechti (Girault)*.	Hemiptera: Miridae	1	2234	5	236
Dicranolaius bellulus (Guerin-Meneville)*	Coleoptera: Melyridae	2	1585	-	-
Ants	Hymenoptera: Formicidae	3	1163	-	-
Oxyopes spp.	Araneae: Oxyopidae	4	1143	1	7523
Nabis kinbergii (Reuter)	Hemiptera: Nabidae	5	944	9	52
Coccinella transversalis (Fabricius)	Coleoptera: Coccinellidae	6	677	10	47
Diomus notescens (Blackburn)	Coleoptera: Coccinellidae	7	575	-	-
Creontiades dilutus (Stal)*	Hemiptera: Miridae	8	493	3	382
Orius spp.	Hemiptera: Anthocoridae	9	294	12	15
Geocoris spp.	Hemiptera: Lygaeidae	10	252	8	82
Chiracanthium spp.	Araneae: Clubionidae	11	190	6	163
Other Spiders	Araneae	12	162	2	3180
Salticid spiders	Araneae: Salticidae	13	121	4	366
Germalus spp.	Hemiptera: Lygaeidae	14	29	-	-
Oechalia schellenbergii (Guerin-Meneville)	Hemiptera: Pentatomidae	15	27	11	37

Harmonia conformis (Boisduval)	Coleoptera: Coccinellidae	16	16	-	-
Mictolestodes macleayi (Csiki)	Coleoptera: Carabidae	17	9	-	-
Micraspis frenata (Erichson)*	Coleoptera: Coccinellidae	18	3	-	-
Mallada signata (Scheider)	Neuroptera: Chrysopidae	-	-	7	159

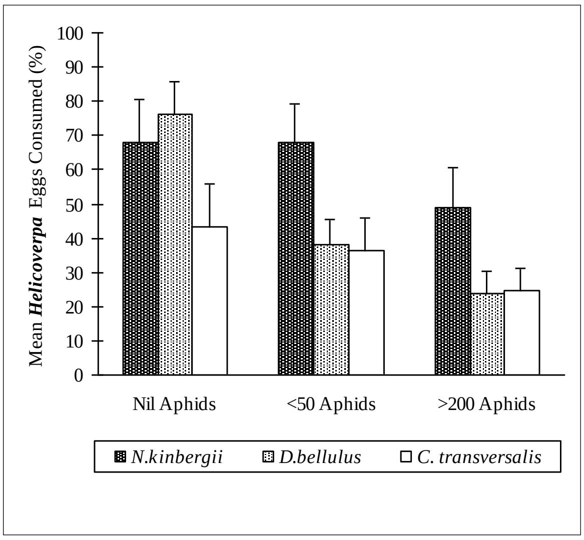
Source: Stanley 1997

Figure 1. Relative numbers of *Helicoverpa* spp., sucking pests, predators, alternative prey and other insects in an Australian cotton crop.



Source: Stanley, 1997.

Figure 2. *Helicoverpa* egg consumption by *Nabis kinbergii*, *Dicranolaius bellulus and Coccinella transversalis* on potted plants, in the presence and absence of *Aphis gossypii.*



Source: Johnson *et al.*, 1998a.