

NATURE'S HELPERS – THE NEED FOR BIODIVERSITY

David Murray

Queensland Department of Primary Industries and Australian Cotton Cooperative Research Centre
PO Box 102, TOOWOOMBA Q 4350

For many years researchers have espoused the view that nature's helpers (natural enemies, beneficials, predators and parasitoids) are a free resource that has not been well utilised in our pest management approaches. We have over-relied on insecticides, many of which were highly disruptive to non-target species. The past few years have seen a remarkable transition where integrated pest management (IPM) has been embraced and successfully applied by many in the industry. Nature's helpers have finally gained some well-deserved recognition. This recent transition is not unlike that which occurred when resistance to pyrethroids first occurred. To place any reliance on endosulfan was almost unthinkable. Some perceived endosulfan as not much better than 'lemonade' (Murray and Cull 1984), yet almost 20 years on, endosulfan still has a very important role in pest management. Such are the changing fortunes in pest management.

Nature's helpers must be the foundation of IPM in today's crop production enterprises; that is not a new message. As our understanding of nature's helpers improves, so too does our desire to increase their contribution. The questions now relate to "How can we enhance predators and parasitoids in our farming system?" Biodiversity is touted to be a solution to this problem. While the logic to increase the diversity of the cultivated landscape makes sense, making an agricultural landscape more diverse will not necessarily lead to greater predator-prey stability (Wratten *et al.* 1998). Biodiversity may well deliver more problems, but most studies show that fewer crop pests are found as the diversity of an agroecosystem increases (Bugg and Pickett 1998). With this background, there is now a move towards more diverse agroecosystems with reduced insecticide use.

Role of natural enemies

While there is a shortage of scientific evidence demonstrating the real value of natural enemies in our cotton system, there is a general acceptance that they are making a difference when allowed to operate in an undisrupted way. Where pest activity permits, the progressive IPM practitioners are moving away from even moderately disruptive products to those with little or no disruptive effect. To take this to the extreme, there are numerous examples where similar yields and/or profit have resulted from truly unsprayed Ingard® fields versus fully sprayed fields.

Quantification of the role of natural enemies has presented a serious challenge to researchers. As a consequence, robust guidelines for practical use of natural enemies are

not available. Currently, the best approach is the predator/prey ratio developed by Robert Mensah (Mensah 2002a). This ratio considers a guild of common predators found in cotton. Many of these are generalists and prefer soft-bodied insects such as aphids rather than *Helicoverpa* eggs and larvae. Furthermore, aphids are easy targets, often abundant and found in clusters in exposed locations. In contrast, *Helicoverpa* eggs and larvae are usually sparsely distributed, with larvae often in sheltered locations on the plant. While laboratory consumption studies indicate how many *Helicoverpa* eggs or larvae can be consumed in a confined space (e.g. Room 1979), these data may be unrelated to actual field behaviour. Other factors may be involved in determining predator effectiveness. It seems many predators are relatively inefficient searchers when it comes to finding *Helicoverpa* prey.

Changes in the abundance of predators occur over time and accurate sampling protocols must be in place if we are to consider predators in our pest management decision-making. The predator/prey ratio relies on visual sampling. Other sampling methods (e.g. suction, beat sheet) are available (Scholz *et al.* 2001), but must be calibrated against the visual method if they are to be applied successfully in determining the predator/prey ratio. Relative sampling efficiencies also change as plants grow in stature.

The predator/prey ratio does not consider the contribution of parasitoids, which in some locations is very important (Scholz *et al.* 2002b). Parasitoids have well-developed behavioural responses to chemical cues from their hosts that lead to more efficient host-finding behaviour. While the contribution of parasitoids can be directly quantified, there is usually a delay of some days before parasitism can be determined visually from collected specimens. Parasitised eggs turn black and *Helicoverpa* larvae can be split to reveal developing *Microplitis* parasitoids within, but new DNA diagnostics testing could be used to quickly reveal a suite of potential mortality agents (Amornsak *et al.* 1998, Anon. 2002).

Contrary to popular belief, the trend in non-disrupted cotton systems is for a gradual build-up of natural enemies as the season progresses, peaking late in the season (Scholz *et al.* 2002a). The mid and late season decline of natural enemy numbers so often reported in studies (Mensah 2002b) may be more a function of disruptive effects of widespread chemical use across the agroecosystem rather than any naturally-induced decline in their abundance.

Role of biodiversity

Having accepted a role for natural enemies, how then do we enhance their effectiveness through biodiversity? A founding principle of biodiversity is to conserve beneficial arthropods that are important for effective biological control by providing them with

alternative refuges. In essence, this means moving towards polyculture and year-round provisioning for natural enemies.

We are now exposed to a plethora of terms – trap crops, refugia, nurseries, sinks and sources and so on – not new in the entomology textbooks, but somewhat new in the context of intensive Australian cotton production. Some degree of confusion has arisen amongst practitioners as to what is the real purpose behind these terms. Whatever their purpose, these habitats offer biodiversity, providing opportunities for natural enemies to persist in ‘non-productive’ patches beside the ‘productive’ cotton crop. Studies by Walker *et al.* (1996) provided some insight into the potential usefulness of various crops to support natural enemies. Lucerne and grain sorghum were two crops rated highly as natural enemy nurseries. Mensah and Khan (1997) exploited this aspect further to develop interplanted lucerne as a trap crop for green mirids. In this system, lucerne has a dual role as a natural enemy nursery and a green mirid trap.

The cotton landscape is essentially ‘barren’ during the non-cropping season, so natural enemies require somewhere to survive this adverse period. If the majority of natural enemies die off or move elsewhere for the winter, then the task of re-colonisation in spring and early summer becomes quite difficult. It is not established how well native vegetation supports cotton’s natural enemies. The nursery crop approach relies on there being sufficient natural enemies within the wider cropping system to colonise the nursery crops in the first place (Walker *et al.* 1996). Simply providing harbourage for natural enemies may not be enough, and placing refugia next to very intensive cultivation may be the agricultural equivalent of establishing a kindergarten next to a busy freeway (Wratten *et al.* 1998).

The spatial and temporal arrangement of refuge areas should be carefully considered. Mensah (1999a) showed that predator numbers declined with increasing distance from interplanted lucerne strips to reach their lowest level 300 m away. Lucerne strips 8-16 m wide are sown every 300 m across cotton fields (Mensah 1999b). Maximum benefit is achieved if the lucerne is well established by the time cotton is planted. There is then the task of moving predators to where they are needed.

It is not a simple matter to move natural enemies from a refuge to a target crop. If food (prey) is readily available in the refuge, most predators will tend to remain where they are. If food becomes depleted, or the refuge host plants become less attractive, natural enemies will progressively move from that area. Food sprays have been used to influence predator behaviour. They work in various ways; they aggregate natural enemies in a ‘treated’ area, arrest their movement once they have arrived, and sustain them if food is scarce (Mensah

2002a). Several food sprays are now on the market and their use has met with varying success.

In providing alternative habitats for natural enemies, we must be careful not to support other pests that could be equally damaging to our crops. For example, current IPM guidelines for mites and aphids recommend the removal of alternate hosts (Mensah and Wilson 1999). These wild or cultivated hosts could also serve as important refuges for natural enemies. If refuges are not well grown, pest species can move to adjacent fields and cause problems. In the case of green mirids, interplanted lucerne strips must be well grown to hold mirid populations. If lucerne hays off from water shortage, green mirid can emigrate to adjacent cotton. Diseases can be maintained or even increased under some crops. For *Fusarium oxysporum vasinfectum*, understanding host range and host plant interactions are essential to reduce levels of field inoculum (J. Kochman pers. comm.).

Understanding biodiversity

Biodiversity includes the numbers of species present, their composition, their structure and their function (Bugg and Pickett 1998). While we have an appreciation of the importance of maintaining biodiversity in our cropping system, our understanding of its complexity is far from clear.

The IPM game is played on an uneven playing field that under a monoculture system appears to favour pest species. Mobility of *Helicoverpa* allows their swift incursions into crop areas. Natural enemies respond more slowly and suffer a lag effect. Unless we have a 'resident' population of natural enemies, the threat of pest damage requires timely intervention. Once we intervene, the system is altered, and return to equilibrium may not be achievable. The chain of events leads to an insecticide treadmill.

Just like their pest prey, predator guilds change from year to year in a highly unpredictable way. Thus it is difficult to plan detailed strategies in advance. Some degree of flexibility is required to respond to such dynamic situations. Evaluation of the enhancement of biological control is a daunting problem, far greater than the 'count and spray' approach of conventional pest management (Wratten *et al.* 1998).

Times are changing. Bt transgenic cotton (Ingard) has seen the pest status of *Helicoverpa* diminish. With the use of fewer broad spectrum sprays targeting *Helicoverpa*, other pests have increased status. Green mirids and stink bugs, for example, also require specific controls that may be highly disruptive to natural enemies. The potential risk of bunchy top transmission by aphids has lowered early-season tolerance of aphids, placing increased demand for their control. Less-disruptive options are constrained by insecticide resistance in cotton aphids.

What experiences have we had – good and bad?

The pest activity of a season has a large bearing on the success of IPM. Experience has shown that natural enemies can manage lower pest densities, with examples where up to 15 eggs per metre were left untreated in the presence of abundant predators. However, 30, 40 or more eggs/m, especially if sustained over several checks, are not readily managed by predators and intervention is usually necessary - and desirable - to avoid damage. This is where area-wide management (AWM) has a role, recognising that *Helicoverpa armigera* activity during a season is largely a function of the local agroecosystem and exploitation of available plant hosts for population increase. If measures are taken to reduce pest populations across the entire farming system in a non-disruptive way, natural enemies conserved under this approach may adequately manage the resulting lower population. Such has been the experiences in some districts over the past few seasons. The cynics would suggest this was good luck rather than good management? Granted, it is not an easy path to travel, but nothing breeds success like success, and most onlookers are envious.

When inspecting a crop, it is always the one or two damaged fruit that catch our eye, missing the fact that most fruit are healthy and undamaged. This really needs to be put into perspective, and increasingly consultants are monitoring fruit damage while tolerating larvae rather than intervening immediately with heavy-handed, knee-jerk responses that decimate natural enemy populations.

The unsprayed cotton refuges implemented under the Ingard Management Plan have contributed to some very positive experiences. These refuges are most rewarding if favourably located upwind of sprayed fields. They can provide a complete learning experience, so don't plant and neglect, but live and grow with the crop.

For the future

Is maintaining biodiversity economically viable? An insecticide dependent approach to insect pest management in cotton is simply not sustainable. Economic, environmental and social issues are already influencing change. Governments and Industry are very conscious of these issues, and considerable investment is being made to foster and support change. Declining economic returns are often the driving force for change. Some regions have experienced the backlash of high insecticide costs, in some cases exceeding \$1,000/ha. This alone is sufficient cause for investigating alternatives to the insecticide treadmill. IPM, as an alternative to the insecticide-dependent model, must clearly demonstrate profitability or the IPM movement will stall.

Nature's helpers are one component of IPM. While the economic data do not directly evaluate natural enemies and biodiversity in IPM, the inference is that less disruptive ('soft') spray programs that conserve natural enemies, as measured by the beneficial disruption index (BDI), on average result in equal or higher profits (Hoque *et al.* 2000). This has been shown to be the case through several seasons of both high and low pest pressure (Dillon and Hoque 2000, and see Hoque *et al.* these proceedings). In large-scale trials, Mensah (2002b) showed his IPM package resulted in equivalent gross margins to conventional insecticide-managed Bt transgenic and non-transgenic cotton crops. Reduced chemical dependence can profit a sustainable, competitive cotton system.

Bollgard II, following on from Ingard, is set to change pest emphasis even further. If a large proportion of the cotton crop is sown to Bollgard II, early and mid season *Helicoverpa* populations emanating from cotton could be greatly reduced because survival on Bollgard II would be negligible. Furthermore, transgenic cotton is imposing diversity through refuge management and contributing to the conservation of nature's helpers by reducing the need for disruptive sprays directed against *Helicoverpa*. This augurs well for the future adoption of IPM and AWM.

Our understanding of biodiversity is underdone. Questions now posed by IPM and AWM groups are stretching the limits of knowledge as it applies to on-farm and farming systems implementation. Wratten *et al.* (1998) suggests we need to understand better three related topics; the spatial dynamics of beneficial arthropods on farmland, the potential negative effects of refugia and the mechanisms involved in functioning of refugia. Without this knowledge, the true implications and potential of farmland refugia will not be understood.

We have come a long way with IPM, but we need to go much further. With this comes a realisation that the diversity of the Darling Downs mixed farming system, once considered the very cause of our *Helicoverpa* problem, may offer the most promise for managing pests in a sustainable way. The tables are turning, and the goal posts are now wider than ever before. Nature's helpers are making a difference.

References

- Amornsak, W., Gordh, G. and Graham, G. 1998. Detecting parasitised eggs with polymerase chain reaction and DNA sequence of *Trichogramma australicum* Girault (Hymenoptera: Trichogrammatidae). *Australian Journal of Entomology* 37:174-179.
- Anon. 2002. Taking the guesswork out of biological control. *The Australian Cottongrower* 23:64.
- Bugg, R.L. and Pickett, C.H. 1998. Introduction: Enhancing biological control – habitat management to promote natural enemies of agricultural pests, pp 1-23. In C.H. Pickett and R.L. Bugg (eds). *Enhancing natural enemies*. University of California Press, Berkeley, California.

- Dillon, M. and Hoque, Z. 2000. An analysis of pest pressure in an area wide management group. *Proceedings of the 10th Australian Cotton Conference* pp.75-83.
- Hoque, Z., Farquharson, B., Dillon, M. and Kauter, G. 2000. An economic evaluation of an on-going IPM program within the Australian cotton industry. *Proceedings of the 10th Australian Cotton Conference* pp.67-74.
- Mensah, R.K. and Khan, M. 1997. Use of *Medicago sativa* (L.) interplantings/trap crops in the management of the green mirid, *Creontiades dilutus* (Stål) in commercial cotton in Australia. *International Journal of Pest Management* 43:197-202.
- Mensah, R.K. 1999a. Habitat diversity: implications for the conservation and use of predatory insects of *Helicoverpa* spp. in cotton systems in Australia. *International Journal of Pest Management* 45:91-100.
- Mensah, R. 1999b. Guidelines for establishing and managing lucerne strips for cotton IPM. In Mensah, R. and Wilson, L. 1999. Integrated pest management guidelines for Australian cotton. Australian Cotton Cooperative Research Centre.
- Mensah, R.K. 2002a. Development of an integrated pest management programme for cotton. Part 1: Establishing and utilising natural enemies. *International Journal of Pest Management* 48:87-94.
- Mensah, R.K. 2002b. Development of an integrated pest management programme for cotton. Part 2: Integration of a lucerne/cotton interplant system, food supplement sprays with biological and synthetic insecticides. *International Journal of Pest Management* 48:95-105.
- Mensah, R. and Wilson, L. 1999. Integrated pest management guidelines for Australian cotton. Australian Cotton Cooperative Research Centre.
- Murray, D. and Cull, P. 1984. Resistance strategy works at Emerald. *The Australian Cottongrower* 5:22-25.
- 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.
- Scholz, B., Cleary, A. and Lloyd, R. 2001. Sheet unbeatable for sampling predators in cotton. *The Australian Cottongrower* 22:14-17.
- Scholz, B., Cleary, A. and Lloyd, R. 2002a. The value of unsprayed strip crops as nurseries for beneficials in dryland cotton on the Darling Downs. *Proceedings of the 11th Australian Cotton Conference*, these proceedings.
- Scholz, B., Parker, N. and Lloyd, R. 2002b. An evaluation of unsprayed INGARD cotton strips as nurseries for beneficials in dryland cotton on the Darling Downs. *Proceedings of the 11th Australian Cotton Conference*, these proceedings
- Walker, P.W., Fitt, G.P., Franzmann, B.A., Lloyd, R.J. and Mensah, R.K. 1996. Alternative crops for producing natural enemies of cotton pests. *Proceedings of the 8th Australian Cotton Conference* pp.247-255.
- Wratten, S.D., van Emden H.F. and Thomas, M.B. 1998. Within-field and border refugia for the enhancement of natural enemies, pp.375-403. In C.H. Pickett and R.L. Bugg (eds). Enhancing natural enemies. University of California Press, Berkeley, California.

... ..

... ..

... ..

... ..

... ..

... ..

... ..

... ..