To help grain growers manage their crop pests, the National Invertebrate Pest Initiative has been set up with the support of the Grains Research and Development Corporation. NIPI pulls together scientists from state government departments, universities, farmer groups and CSIRO and its coordinator is Dr Gary Fitt from CSIRO Entomology. Australian Grain will be presenting articles reviewing the current knowledge of invertebrate pests – and their management in Australian grain systems.

Host plant resistance and IPM in Australian grain crops

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For many years synthetic pesticides have been the mainstay of pest control for farmers. They are effective and affordable. But with their widespread and sometimes indiscriminate use came problems. Pests developed resistance and beneficial insects, which often kept secondary pests under control, were killed.

In response, many farming systems have moved to integrated pest management (IPM) packages that combine cultural, biological and chemical tactics. Host plant resistance (HPR) is a fundamental component of many IPM strategies.

HPR results from genetically based changes in the morphology (such as, leaf shape, stature, hairiness), chemistry (for example, levels of toxins, growth retardants) or phenology (influence of climate on annual phenomena such as flowering) of the plant. HPR is often targeted at specific pests and provides a crop variety with a level of in-built protection against the pest which will be reflected through higher yield during an outbreak of that pest relative to more susceptible varieties.

HPR is usually categorised as:

- **Antibiosis** – causes physical damage to the feeding pest often resulting in death or reduced longevity and reproduction;
- **Antixenosis** – affects the behaviour of a pest so that fewer of them feed on a resistant plant than would choose to feed on a susceptible one; and,
- **Tolerance** – enables a plant to withstand or recover from pest damage better than a susceptible plant would.

Antibiosis and antixenosis cause a response in the pest when it tries to feed, lay eggs on or shelter in a resistant plant. This means plants with antibiosis or antixenosis can 'select' for resistant individual pests thus leading to the possible development of pest biotypes that are themselves resistant to the resistant plants.

A Helicoverpa larva. Helicoverpa is a pest of a number of grain crops.
(Photo: CSIRO Entomology)

Plants with tolerance don't exert this selection pressure.

As with most methods of pest control, HPR on its own is seldom enough but as part of the multi-pronged attack of an IPM package can be extremely useful. The use of even partially resistant varieties can have a significant cumulative effect on pest populations over time, thereby reducing the use of pesticides. Importantly, this reduction in pesticides makes the use of resistant crop varieties in IPM compatible with the use of biological control agents and other natural enemies.

Areas of research on HPR in Australian grain crops include aphid resistance in legumes and cereals, sorghum midge resistance and pest resistance in canola. There is also work on the use of transgenic technology to enhance HPR in grain crops.

Aphid HPR in legumes

Bluegreen and cowpea aphids are the two main aphid pests of pulses and lupins in Australia. When conditions are right, most pulses (except chickpea) suffer from aphid outbreaks. Aphids can cause substantial yield losses in lupins to the extent that attempts to grow yellow lupin in Western Australia have been unsuccessful because of the susceptibility to aphids of cultivated varieties like Wodjil.

Lupin breeders at the Department of Agriculture and Food, Western Australia have been investigating aphid resistance for more than 20 years. They have successfully developed narrow-leafed lupin varieties with increased resistance to aphids in general. But it is possible that green peach aphid may now become more of a problem because they can adapt to the higher levels of alkaloid in resistant varieties. Green peach aphid is harder to control than other aphids because of its resistance to many insecticides.

In lucerne, most varieties now carry some antibiosis type resistance to bluegreen and spotted alfalfa aphids. Australian breeders

have also had success in breeding aphid resistance into annual pasture legumes.

Researchers are using barrel medic to investigate the mechanisms underlying aphid resistance in plants. Work on resistance genes against bluegreen, spotted alfalfa and pea aphids shows they belong to a class of genes that stimulate plant defences when aphids feed.

Aphid HPR in cereals

In northern Australia, cereal aphids are generally not a problem as they are controlled by natural enemies whereas, in southern Australia, they are important vectors of barley yellow dwarf virus. As yet, there has been no work in Australia on developing cereals with resistance to aphids that are already present in Australia.

But the recent appearance of virulent biotypes of Russian wheat aphid (RWA) in the US and South Africa has reinvigorated a pre-emptive breeding effort against this exotic pest. Australia is the only major cereal-growing area in the world that does not have RWA.

RWA poses a huge threat to Australia's wheat and barley industries if it gets here as even low numbers can cause considerable damage and yield loss. The aim of current research is to have resistant varieties that could be deployed in response to an incursion.

Sorghum resistance

Grain sorghum in Australia has few major insect pests, among them sorghum midge and *Helicoverpa armigera*, which can cause economic damage during panicle flowering and grain filling. Breeding for insect-resistance traits in Australian sorghum has therefore been directed at protecting the panicle.

One outcome of the research is a trait which changes the structure of the floret and results in reduced oviposition (egg laying) by sorghum midges. It was developed by the Queensland Department of Primary Industries and Fisheries in partnership with seed companies and is now incorporated into commercial hybrids (see next article).

In the late 1990s, another mechanism of resistance in Indian grain sorghum – which involves both antifeedant and lethal effects on midge larvae – was incorporated into the Australian sorghum breeding program. Research into the genes involved is well advanced. Incorporation of this resistance into commercial midge-resistant hybrids once the genes are identified should be rapid and could result in the midge

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Aphids can cause substantial yield losses in lupins. (Photo: Carl Davies, CSIRO Plant Industry)

becoming a 'forgotten pest' of Australian sorghum.

Pest resistance in canola

In Australia, canola (which consists of different cultivars of oilseed rape) is attacked by at least 30 invertebrate pest species. Until recently, canola growers relied on chemical pesticides but increasing pressure to reduce pesticide use and problems with pesticide resistance are driving a move to IPM. The development and adoption of pest-resistant varieties of canola is a part of this.

Research on HPR in canola started overseas in the early 1980s and studies have shown that the different types of resistance can confer resistance to different insect pests. For example, both antixenosis and tolerance were found to be mechanisms of resistance to the flea beetle in two canola varieties and physical or chemical characteristics of canola leaves can also be the mechanism of resistance to diamondback moth (DBM) in some cultivars.

Australian research in this area began in the early 1990s. Preliminary screening showed that some northern hemisphere varieties were less vulnerable to redlegged earth mite (RLEM), a serious establishment pest, at the cotyledon stage compared to Australian varieties.

The GRDC then funded a project to further investigate canola resistance to RLEM. Large-scale glasshouse screenings and field trials identified four lines that suffered significantly less damage from the mite than the susceptible commercial cultivar, Oscar. The mechanisms underlying this mite resistance are still unclear.

CSIRO, in collaboration with canola breeders from the New South Wales and Victorian Departments of Primary Industries, conducted screening tests on a number of varieties. They focussed on RLEM and DBM, a serious pest at flowering and budding stages.

Glasshouse tests showed varietal differences in response to RLEM and in attractiveness to DBM for oviposition. When exposed to RLEM, some varieties suffered a significant reduction in both feeding damage and effect on growth performance. Oviposition by DBM was significantly lower in a few varieties. Field trial results generally supported the glasshouse findings. Although the mechanisms of resistance to RLEM and DBM are, as yet, unknown, it may still be possible to use them in IPM for canola production.

The large number of commercial canola varieties in Australia will be a valuable resource in the continuing search for resistance to invertebrate pests.

Pest resistance and genetically modified plants

Rapid advances in genetic engineering are making more and more plants available that express characteristics valuable for agriculture, including resistance to key pests. Crops with traits targeting insect pests make up around 10 per cent of the 114 million hectares of GM crops currently being grown globally. Most of these contain *Bacillus thuringiensis* (Bt) toxins which target moth pests. The best known of these is cotton.

In grain crops, there could be a role for Bt genes to provide control for some lepidopteran pests such as Helicoverpa spp. and DBM. Other recent advances may offer options for aphids and plant leafhoppers.

But before GM grain crops become a reality, there are significant hurdles to overcome. One is public acceptance of GM grain crops for human food. Another is the potential for pests to develop resistance to the toxins produced by introduced genes such as Bt genes. Strategies such as the refuge strategy in cotton would need to be in place to minimise this risk.

If the target is a pest such as Helicoverpa and is widespread, polyphagous (able to feed on various foods) and mobile, then the complex question of how to integrate the deployment of the transgenes across a range of crops arises. Bt corn is already commercialised in several countries and there are proposals to introduce Bt genes into a range of crops including sorghum, canola, lupins, field peas and chickpeas.

Managing the deployment of Bt genes in grain crops, when the same genes may already be widely in use in crops such as cotton, requires careful consideration.

These issues need to be considered at the regulatory level before research funds are committed or commercial releases considered to ensure resources are not wasted on products unlikely to get regulatory approval. Despite the difficulties, it is likely that genetically modified crops with enhanced pest resistance will play a significant role in IPM for Australian grains in the future.

In Australia, canola is attacked by at least 30 invertebrate pest species.
(Photo: David McClenaghan, CSIRO Entomology)

This article is a summary of a paper by Hainan Gu, Owain Edwards, Adam Hardy and Gary Fitt*: *Host plant resistance in grain crops and prospects for invertebrate pest management in Australia: an overview* which appeared in the Australian Journal of Experimental Agriculture 48 (12): 1481-1493. It is one of a suite of papers published in this special edition of the journal.

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