3 F: CROPS AND PEST CONTROL

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Pest losses in crops

Over the past 25 years the total world crop production has increased significantly. The global human population is expected to increase to 10 billion by the middle of this century. There will be a need for more food and fibre coming from less land, less water and using less labour. Vulnerability of crops to pests, weeds and diseases increases with increasing intensity of production. The overall global loss of crop production due to weeds, pests and diseases is estimated to be 42%, but if physical, biological or chemical means were not used to protect crops this would rise to 70%. However, the focus of this paper is on pests. Losses due to pests are 16% in the absence of crop protection, but still average 7% in the presence of crop protection.

Agricultural production in Australia is valued at $22 billion, with exports making up $16 billion. Losses due to invertebrate pests in the presence of current controls are valued at $3 billion. Total area under cropping in Australia is about 18 m ha. Insects infest about one quarter of this in any one year. Most of the infested area is treated with insecticides. The proportion of a crop infested varies considerably between crops, being lowest for the cereals, wheat and barley (16%), increasing with sugar cane (21%), lupins (41%), chickpeas (46%), peas (79%), canola (83%), and highest levels in cotton, rice and sorghum where the entire crop is infested (Table 1). Of grain going into storage on farm, 62% is treated for insects at time of storage. Subsequently, 17% of grain requires further treatment for insect control. All grain in bulk storage is treated. Control of pests in stored grain in Australia costs an average of $10-15/tonne.

Table 1. Areas of selected crops infested with pests in Australia

Crop	GVP ($m)	Area (000 ha)	Area infested (000 ha)	Area treated (000 ha)
Barley	885	3344	550	540
Canola	638	634	525	521
Chick pea	94	197	90	85
Cotton	1353	378	378	378
Lupin	244	1080	440	432
Peas	93	316	250	246
Rice	332	152	152	152
Sorghum	285	544	544	544
Sugar cane	1044	377	80	75
Wheat	3860	10937	1750	1725
Total	**8828**	**17957**	**4759**	**4698**

GVP (Gross Value of Production) data from ABS 1998-9. Other information from CABI Crop Protection Compendium; global module data for 1997.

Integrated pest management

Use of broad-spectrum insecticides provides a simple and effective control. However, excessive reliance on insecticides to control pests can lead to problems that threaten production, sustainability, health and the environment. To minimise these problems growers must diversify, using a combination of other forms of pest control practices. This is what scientists now term integrated pest management (IPM). The aim is to keep pests below economically damaging levels, rather than seeking to eradicate them. It depends on reducing chemical use and relying where possible on non-chemical methods of control. When chemicals are used they should be selected and applied in time and space so as to minimise any adverse effects on beneficial organisms, on humans and on the environment, and development of pesticide resistance in pests. IPM is knowledge intensive technology, requiring training for farmers, for researchers, and for extension specialists. Combinations of short and long-term methods are used. For any IPM package the most likely path for success is to start at the regional scale, and build up to the national scale.

Biological control

In biological control natural enemies are used to keep pest populations at acceptable levels, usually in combination with other control methods. The natural enemies may be predators, parasitoids or pathogens. Predators, such as spiders, ladybirds, lacewings or predatory mites, usually feed on a range of different insects. Parasitoids lay eggs on one host insect, and the larvae live and feed on the host, which dies (true parasites do not kill their hosts). The adult parasitoids are typically honey feeders. Pathogens may be bacteria, fungi, viruses, nematodes or protozoa.

There are several ways that natural enemies can be used in biological control. Management of the crop and its surrounding habitats can enhance the abundance of native parasitoids or predators. Parasitoids and pathogens can be mass reared in the laboratory, and inundative releases made in the field for biological control, or as biopesticides. Classical biological control is where natural enemies are introduced from overseas, usually from the country of origin of the exotic pest. Only species that are highly host specific overseas are introduced to Australia, where further detailed host specificity testing is carried out in high security containment facilities before authorities can give permission for agents to be released. It is essential that highly specialised and experienced biological control scientists carry out this work.

Virtually all crops and many pests are exotic to Australia, being introduced in the last 200 years. Classical biological control in Australia is most effective on exotic pests (43% of introduced agents successful), and least effective on native pests (13% successful). Some species are completely controlled by introduced parasitoids (white wax scale, greenhouse whitefly). Some are controlled over only part of their range (bluegreen aphid, green vegetable bug). In some, control is achieved with a combination of introduced parasitoids and plant resistance (spotted alfalfa aphid, woolly aphid). In red scale and yellow scale, control is with a combination of introduced and indigenous parasitoids and predators.

Biotechnology

In the area of transgenic and genetically modified plants biotechnology has produced insect resistant transgenic plants. For example, transgenic plants resistant to pests have been developed by transferring a gene from the soil bacterium, *Bacillus thuringiensis* (Bt), for a natural toxin. Current products will be of more benefit to high-input large-scale agriculture, than to poorer farmers. A potential threat to this technology is the development of resistance in pests to toxins in transgenic plants. Area-wide management of cotton pests in Australia involves the integration of methods including transgenic plants expressing Bt, trap crops, resistance management strategies (RMS), natural plant resistance, and enhancing the impact of beneficial insects and viruses. Biotechnology has the potential to deliver a range of exciting novel solutions to pest control, but the technology is still at an early stage of development, and practical contributions are so far limited.

Chemical control

Pesticides remain a critical part of most IPM programs. The potential of pesticides to cause unwanted side effects means that their use will be targeted and used on a needs basis where possible rather than prophylactically. Some insecticides not only kill the pests but also deter them from feeding. A number of new compounds are being brought to market that have a greater diversity in chemistry and mode of action, such as inhibitors of respiratory processes, molecules that disrupt insect endocrine systems, and those acting on novel sites in the insect nervous system. These new compounds have modes of action outside the most common actions on inhibition of acetylcholinesterase (organophosphates and carbamates), and the opening of voltage-gated sodium channels (pyrethroids). This will open new opportunities for IPM.

Cultural control

This includes any agronomic practices that improve yield but reduce pest populations directly, or by enhancing the abundance of beneficial natural enemies. The practices which have worked include ploughing, burning stubble, stubble retention, timing of planting, crop rotations, effect of fertilisers, use of susceptible trap crops to divert pests from the main crop, effects of shading, sanitation of fields and of equipment, and intercropping. There are undoubtedly other methods that also reduce pest abundance.

Host plant resistance

Resistant varieties are an important component of IPM, and they can be easily incorporated with other control methods. Plant resistance may break down over a period of time in the field, and there is a continuing need in crop breeding programs to select new varieties to replace the old ones. Very heavy infestations of pests can cause substantial damage to resistant varieties. Three types of resistance mechanisms have been described. First is tolerance, where the plant is able to compensate for the pest attack so that no reduction in final yield occurs. Second is Antixenosis, where the plant characteristics have an adverse effect on the behaviour of the pest, usually expressed as reduced feeding or reduced egg laying. Third is Antibiosis, where the pests feed but factors in the plant have an adverse effect on them, usually expressed as reduced growth and thus rate of multiplication, or on survival. Level of resistance to pests varies among plant varieties.

Physical control

The manipulation of the physical environment of grain during storage can be used to manage insect pests. Storage pests generally develop fastest at 25-30°C, and so cooling grain will reduce their rate of development. Longer-term storage losses can be prevented by cooling aeration, if the system can be sealed so that air input matches the storage loss rate. The use of heat to control insects in bulk grain is usually considered too expensive, but new technologies are being developed in Australia to overcome this. Novel methods for disinfestation of grain being investigated include the use of sorting and percussion processes.

Control using semiochemicals

Semiochemicals are volatile compounds released by insects for communication between the sexes. Sex attractants allow males to find and recognise females of the same species. They have been used in several different ways: for pest detection, for surveillance, for monitoring, for control by mass trapping, for mating disruption, and in attract and kill strategies. Success has probably been greatest in the horticultural industries. The method does not work well at high insect densities or with species where adults are capable of multiple mating. The technique is well suited for use in IPM in high-value crops, but lack of a good understanding of insect biology and behaviour is limiting more widespread use.

Preventive control

Preventive measures are taken to reduce the chance of exotic insect species becoming a pest. This is usually through quarantine supported by regulatory control. The steps to prevent incursions are to clean up the produce or exclude it before importing, to detect incursions in Australia before they spread, inspection and extermination, surveillance, and finally eradication if an incursion does become established. Over the last 30 years incursions by 53 new pest species have been reported in Australia. Only a few of these become established, and in turn only some of these become pests. Eradication is the first step if possible, and if not, then containment. Governments are responsible for managing the emergency responses following an incursion that may include eradication or containment, whilst industry is responsible for suppression of or living with the pest.

Conclusions

No single control method is going to be sufficient to manage pests on crops. Increasingly, pest control will have to be sustainable, with less reliance on chemical pesticides. There is a future threat to the continuing use of chemicals should there be widespread and uncontrollable insect resistance. It is likely that there will be a wider adoption of quality assurance (QA) programs when growing crops, with more reliance on IPM, which will require more interdisciplinary skills.

Discussion notes

- Monocultures are more likely to lead to pest outbreaks, and larger paddocks will obviously increase this chance. Diversity, either in the crop, or more usually in the edges of crops, tends to support natural predators and parasites, which will help to control the pest, or prevent pest outbreaks. Many parasitic wasps need honey as adults to develop their eggs, and flowering plants, including weeds, can increase their abundance. Currently, investigations are under way to determine whether pastures containing several legume species are damaged by pests less than pastures containing a single species.
- Organic farming really brings up a different set of issues, because it may be more about the way that crops are grown than the shape or size of paddocks. Anything that

increases diversity will help to give niches which allow natural enemies to develop their populations.

- Temperature control is a good way of reducing pest breeding in stored grain. Cooling prevents the build up of populations. Grain pests are less of a problem in Canada because grain is stored at lower temperatures. High temperatures can be used to disinfect grain, but the technique is not yet developed enough for general use.
- Locust plagues have devastated crops since agriculture was first developed in the Middle East over ten millennia ago. In the modern world, this is a classic insurance type problem. Most farmers/people will not be affected, but for those that are it is a catastrophe. Is it better to try to control a very mobile pest or give financial compensation to the losers? For mobile pests, control at the breeding centres, usually in inland Australia, is a sensible way to prevent the plague from developing, but it is not easy to achieve. Biological control is preferable to the traditional use of chemicals (or possibly both). Many biological control agents cannot multiply fast enough to stop outbreaks. CSIRO's Richard Milner has been trialling a fungal pathogen, a metarhizium species, which does have the ability to multiply rapidly under suitable conditions.
- Existing types of transgenic cotton will control the major pests, which are chewing insects, and there is a substantial reduction in the use of chemical sprays. This is a desirable environmental outcome, and is leading to an increase in populations of beneficial natural enemies, and it reduces costs of production. However, it seems to be leading to an increase in sucking pests to fill the gaps. Nature is filling the vacuum!
- Farmers will make decisions on the area of irrigated crops they plant based on the price of water or of licensed area for irrigation. We should be able as a society to make a decision about this on the basis of sustainability. This is a different issue from the ability to control pests more effectively or to produce better cotton varieties by plant breeders.
- Rabbits are still the major vertebrate pests in pastures. Mouse plagues are more of a problem in grain crops. Calcivirus is reported to be controlling rabbits in drier areas but not wetter areas. The Cooperative Centre for Pest Animal Control is involved in ongoing fertility control for rabbits. A virus is one of the options which is being considered.

Further reading

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