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When will integrated pest management strategies be adopted? Example of the development and implementation of integrated pest management strategies in cropping systems in Victoria

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Abstract. This paper discusses the development and implementation of integrated pest management (IPM) strategies for broadacre cropping in Victoria, Australia, with reference to other crops and also the levels of adoption of IPM in Australia and overseas. Levels and rates of adoption are mostly low but with some exceptions. The reasons for differing levels of adoption include the failure of strategies to successfully deal with all pests, the lack of motivation to change to using IPM given current successful pesticide-based controls, and the poor availability of IPM advisors in the field. This paper outlines how IPM strategies for wheat, barley and canola crops were developed and implemented using a collaborative approach between farmers, agronomists and entomologists. It was found that although there were no existing specific IPM strategies for the crops grown in the region of south-eastern Australia, there was sufficient information for farmers to start using an IPM approach. This paper gives a case study of implementing change to IPM from conventional pesticide spraying, including the development of a course in IPM for growers and agronomists. It focuses on the process of changing practices and information transfer rather than on entomological details.

Integrated pest management

There are at least 21 definitions of integrated pest management (IPM) (Bajwa and Kogan 1996; Food and Agriculture Organisation 2000) but the term is taken here to mean using biological, cultural and chemical control methods in a compatible way to manage pest problems (Alston and Reading 1998; Horne and Page 2008). Some definitions are presented in Table 1. IPM is an approach that is widely seen as desirable and is promoted by many agencies worldwide, including the United Nations, the World Bank and the Food and Agriculture Organisation (Maredia 2003; Olsen *et al*. 2003) and also government agencies in Australia (Williams and Il'ichev 2003). The term 'pest' can be applied to invertebrates, vertebrates, weeds or diseases, but the emphasis in this work was on invertebrate pests and the reduction in use of insecticides. The toxicity of insecticides to a wide range of organisms makes reduction of these products an important first step in an integrated approach.

IPM is well known and used in many horticultural industries but is a relatively unknown and little-adopted concept in broadacre farming in Australia. A recent summary of IPM in Australia made no mention of IPM in broadacre cropping (Williams and Il'ichev 2003). Despite the perceived advantages of IPM there are also disadvantages (Table 2) and despite the efforts of many research entomologists, studies worldwide have often shown poor rates of adoption (e.g. Wearing 1988; McNamara *et al*. 1991; Herbert 1995; Sivapragasam 2001; Bajwa and Kogan 2003; Olsen *et al*. 2003). Even in horticulture, where the theory of IPM is well developed, achieving widespread adoption on farms remains a challenge (Boucher and Durgy 2004; Page and Horne 2007). The present paper describes how IPM strategies in broadacre crops in Victoria were developed and implemented by entomologists using proven extension principles.

Adoption or non-adoption of IPM by farmers

One likely factor for the poor rates of adoption in some cases is that researchers have concentrated on a single pest and have not dealt with all pests in a crop (Blommers 1994; Sivapragasam 2001; Olsen *et al*. 2003). Integrated mite management in apples (Albajes *et al*. 2003) is one example of this approach. Also, when the current pesticide-based strategies work, then there is an absence of a crisis to demand an alternative approach. When pesticide-based strategies work and when information given to farmers is complex, and is given without contact with an IPM expert to help with implementation, then it is easier for a farmer to use an established, proven and simple pest-control method that relies totally on pesticide application. For an IPM strategy to be effective it must deal with all pests in the crops (Trumble 1998; FAO 2000) and ideally would be as easy to implement as a pesticide-based strategy.

A survey of Australian potato growers showed that adoption rates varied from nearly 0–100%, depending on the presence or absence of an advisor on IPM (Horne *et al*. 1999). It has also been noted that the rate of adoption measured depends largely on the definition of IPM used (Bajwa and Kogan 2003). Studies in fruit (Alston and Reading 1998), brassicas (Sivapragasam 2001), vegetables (Page and Horne 2007) and other crops (Herbert 1995; Maredia 2003) also found that the presence of a

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Table 1. Some definitions of integrated pest management
Source: Bajwa and Kogan (1996)

Definition	Reference cited
Applied pest control that combines and integrates biological and chemical control.	Stern *et al*. (1959)
Integrated control is a pest population management system that utilises all suitable techniques, either to reduce pest populations and maintain them at levels below those causing economic injury, or to so manipulate the populations that they are prevented from causing such injury. Integrated pest management is a strategy of pest containment that seeks to maximise natural control forces such as predators and parasites, and to utilise other tactics only as needed and with a minimum of environmental disturbance. Integrated pest management, in its simplest form, is a control strategy in which a variety of biological, chemical and cultural control practices are combined to give stable long-term pest control.	Smith and van den Bosch (1967); Glass (1975); Ramalho (1994)
IPM means 'intelligent pest management'.	Zweig and Aspelin (1983)

Table 2. Advantages and disadvantages of adopting integrated pest management

Advantages	Disadvantages
Reduced dependence on pesticides	More complex than control by pesticide alone and requires a shift in understanding
Increased safety to farm workers, spray operators and the community	Requires a greater understanding of the interactions between pests and beneficials
A slower development of resistance to pesticides	Requires a greater understanding of the effects of chemicals
Reduced contamination of food and the environment	Increased time and resources
Improved crop biodiversity	Level of damage to the crop may initially increase during transition to an integrated pest management program, in some horticultural crops

specialist IPM advisor working closely with small groups of farmers is necessary for successful adoption of IPM (Olsen *et al*. 2003). These reports give a range of reasons for the poor rates of adoption and some of these are listed here:

- Too few entomologists as advisors
- Focus on research rather than implementation
- Too complex
- No local advisor
- Not enough information
- Chemical-based control still works

To improve the rate of adoption of IPM it is necessary to deal with each of these issues. However, it is also well known that the chemical industry supports pesticide-based approaches to pest control whereas the support of IPM depends on a lesser (public)-funded strategy (Herbert 1995; Bajwa and Kogan 2003). As shown in Table 3, there are usually large differences between the features of pesticide technology and IPM that help explain the often slow rate of change to using IPM. However, the two main factors are that pesticides are still easy to apply and are relatively cheap (Albajes *et al*. 2003).

Table 3. Comparison of integrated pest management and chemical-based supports
Derived from Bajwa and Kogan (2003)

Pesticides	Integrated pest management
Compact technology	Diffuse technology with multiple components
Easily incorporated into regular farming operations	At times difficult to reconcile with normal farming operations
Promoted by private sector	Promoted by public sector
Aggressive sales promotion supported by professionally developed advertising campaigns	Promoted by extension personnel usually trained as educators not as salespersons
Results of applications usually immediately apparent	Benefits often not apparent in the short-term
Consequently, pesticide technology was rapidly adopted	Consequently, adoption of integrated pest management technology has been slow

In broadacre cropping and grazing in Australia the regular use of broad-spectrum insecticides and miticides has been viewed as being good farm practice (e.g. TimeRite sprays for *Halotydeus destructor* (Tucker) (red-legged earth mite) (http://www.timerite.com.au/, verified 22 October 2008) and calendar-based sprays for aphids using synthetic pyrethroids (Thackray *et al*. 1999). The routine spraying of synthetic pyrethroids on wheat crops (*Triticum aestivum* L. em. Thellin) is also advised in the USA (Roberson 2007). In general the products used are low cost compared with other farm treatments, they usually achieve immediate results and their application can be combined with other farm applications such as herbicide spraying and fungicide treatments.

The small cost and convenience aspect of the current system has encouraged the regular use of insecticides, even if the application may not have been necessary. Application of insecticides even when no pests were observed has been known from other crops before IPM was adopted [e.g. rice (*Oryza sativa* L.) production in Indonesia (Oka 2003)]. The addition of an insecticide was also seen as an 'insurance policy' (Stoner *et al*. 1986), to guard against potential pest build-up in the future. Insecticide treatments are widely adopted and are currently the basis for most pest-control activity in cropping in Australia (Gu Fitt and Baker 2007; J. Cameron, Independent Consultants Australia, pers. comm.). The type of insecticides used are broad spectrum and known to kill beneficial species such as carabid beetles (Coleoptera : Carabidae) (Curtis and Horne 1995), which are important biological control agents (Horne 2007).

Case study: examples of IPM being implemented in Victoria, Australia

Conventional practice

The established practice (before adopting IPM) within the group of farmers and agronomists discussed in the present paper can be summarised as follows. Synthetic pyrethroid or organophosphate insecticides were sprayed at or near the time of planting to control establishment pests such as *H. destructor* in *Brassica napus* L. (canola) crops. These were used routinely on most paddocks or as a reaction to observed damage. Similarly, molluscicide baits were usually applied routinely or at the first signs of damage by slugs such as *Deroceras reticulatum* (Muller) (Mollusca : Limacidae) or *Milax gagates* Draparnaud (Mollusca : Milacidae) in *B. napus* (canola) crops. Repeated applications of insecticide or bait were made if damage continued. *T. aestivum* (wheat) was sprayed with a synthetic pyrethroid insecticide at 3 and 6 weeks after crop emergence for control of aphids and barley yellow dwarf virus. *Hordeum vulgare* L. (barley) was often sprayed with insecticide for armyworm.

Advice on pest control has been given by agronomists who were also advising on a range of agronomic issues. However, most agronomists are not trained in entomology and, in the absence of expert entomologists, relied on accepted pesticide-based recommendations. Advice that was unproven in the absence of specialist entomological support was considered risky. The result was that the routine use of cheap broad-spectrum insecticides had become standard practice.

Except for the few cases of control failure (e.g. with insecticide-resistant pests such as *Plutella xylostella* (L) diamondback moth) the insecticides usually worked with no apparent disadvantages. Control of invertebrate pests is just one part of farm management and when the insecticide approach works it is seen as a fairly minor part. So the problem in proposing an IPM approach in the absence of a crisis is why would farmers and their advisors want to change from something that is simple and that works to something more complex and risky?

IPM in Victorian cropping systems

In 2002, entomologists from IPM Technologies (Hurstbridge, Vic.) began working with a group of 15 collaborating farmers and their agronomists near Inverleigh, Victoria (38°06′00″ : 144°03′00″) to investigate the practicality of an IPM approach in broadacre cropping. There was interest amongst this group in sustainable farm practices, including reducing reliance on insecticides. A basic IPM strategy was developed from existing entomological information, discussions with collaborating farmers and agronomists and field observations. It aimed to increase populations of resident beneficial species to deal with resident (establishment) pests and also to use transient beneficial species to help control transient pests without disturbing populations of either resident or transient beneficial species. The approach involved: (i) correct identification of pests and beneficials; (ii) eliminating insecticide sprays when insufficient pests were present; (iii) using insecticides in the least-disruptive way; and (iv) using cultural controls such as time of planting. There was also interest in controlling pests in stubble-retained systems, as there was a perception of increased pest problems with this method, as has also occurred overseas (Stinner and House 1990).

Collaborating farmers agreed to nominate three paddocks [one each of *B. napus* (canola), *T. aestivum* (wheat) and *H. vulgare* (barley)] on which they would follow a basic IPM strategy on a commercial scale. The farmer received regular monitoring of the nominated paddocks by entomologists and an agronomist. Monitoring was achieved using standard techniques including pitfall traps, direct searching and suction sampling in addition to the agronomist's regular monitoring. The monitoring led to the identification of beneficial insects and mites, correct identification of pests and the trend in numbers of pests relative to numbers of beneficials. A collaborative decision was made each week during establishment of canola and at key times for both wheat and barley, based on the results of monitoring, past experience and implications of pesticide applications on the biological control of other pests. The results of the first year of trialling this approach on a commercial scale were a reduction in insecticide use (no insecticides were sprayed compared with routine applications the year before) and better pest control, primarily through better identification of pests [e.g. *Forfucula auricularia* L. (European earwigs) were recognised as causing damage that had previously been blamed on slugs]. The farmers and agronomists were satisfied with the results and decided to apply the IPM approach on more paddocks the following year.

Although the answers to the pest problems on these farms were in fact quite simple the outcomes have been massive. The farmers have greatly reduced their reliance on insecticides and are now using IPM on the whole farm. On some of these farms no insecticides at all have been applied via a boom spray in the last 5 years (Horne and Page 2008).

Development of IPM to a wider audience

These successful trials of IPM on a commercial scale led to the development of an IPM training course for farmers and their agronomists as part of a project called 'Grain and Graze' being conducted in the Glenelg-Hopkins and Corangamite catchment management areas in Victoria (Land and Water Australia 2008). The course was based on the elements of a pasture productivity program conducted in southern Australia in the 1990s (Tromph 2001). Twenty-two people enrolled in the course, with approximately half being district agronomists. It was considered important to have both farmers and their agronomists involved at the same time, so that any decisions in this new approach were taken jointly. Following initial training workshops, the course involved field observations and decision making using an IPM approach in commercial crops over a cropping season.

The aim of the course was to keep the information clear and concise and, most importantly, to change insecticide usage. The participants needed to understand how insecticides fit within an IPM strategy, including the effect that they have on beneficial species. Although the course included a component on insect identification it was not an entomology course. Its purpose was to show that there are a whole range of insects that live in crops, many of which are beneficial and can be of great value or benign and neither a pest nor biological control agent.

Where possible the course involved group discussion. The combination of entomologists with specific IPM knowledge, agronomists with good understanding of local issues and farmers with their own experiences resulted in the development of very achievable and practical IPM strategies for the crops nominated using the combined available knowledge. All participants developed a comprehensive IPM strategy for each of their crops, which they were able to implement and test with support from IPM specialists. An example of an IPM strategy for canola has been given by Horne and Page (2008). Each grower and agronomist was able to highlight specific issues to address, and it was noted that the farmers were often willing to take more risks until a compatible set of proven control options was developed for each farm.

It was acknowledged in the course that the most difficult aspect of implementing an IPM strategy would be the decision making during the season, and in particular for control of establishment pests in canola. Damage to the plants during the cotyledon stage could result in crop loss and possibly require replanting. The strategies developed tried to ease this pressure as much as possible by planning ahead and possibly using seed dressings. However, at some point the decision to use an insecticide or not would have to be made. The questions to be answered would be: Will the crop suffer economic loss this week if an insecticide is not used? If we are spraying a fungicide or herbicide should we include an insecticide? These are the very real and very stressful decisions that need to be made in order to implement IPM.

Field sessions were required as part of the course follow up. Course participants and entomologists met in nominated paddocks at critical times to discuss and answer any questions or concerns of the group. These visits were often followed by several phone calls until an agreed decision was made.

The answers to most of the questions raised did not require detailed scientific data but did require confirmation that there was no immediate cause for concern. It is important to remember that insecticides were used because they are cheap, effective and the accepted practice. It was changing this attitude that was the barrier to adoption of IPM and not a demand from farmers for more data.

All participants successfully implemented the IPM strategies on the nominated paddocks and have continued to do so. After the initial year of trialling this approach the decision making has become considerably easier. Some farmers now value their populations of beneficial insects so much that it is harder for them to decide to use a broad-spectrum insecticide even if some pest damage may occur, because they know what they will lose and the other pest problems that may arise as a result.

Discussion

Successful examples of IPM adoption have usually involved several key elements – collaboration between farmers and advisors, local demonstrations and availability of expertise (e.g. Horne *et al.* 1999; Sivapragasam 2001; van Lenteren 2003; Heisswolf and Kaye 2007). The adoption of IPM in crops and pastures described in the present paper has been achieved through a combination of available knowledge, rapid testing of IPM approaches at a farm scale and the application of proven extension principles. The use of such a farmer-participatory approach is recognised as an important tool in extension generally (Black 2000; Murray 2000) and is also known to be a successful means of delivering IPM training and research (Dent *et al.* 2003). Critical in the successful adoption of IPM was the willingness of growers to be involved in commercial-scale trials following their acceptance of the IPM principles outlined in workshops and courses. An essential part of this adoption has been the close one-on-one relationships developed with experts in the paddock. It enabled uncertainty over observations to be resolved and allowed tactics to be discussed. The effective answering of questions by experts in the paddock and the access to experts to give an immediate response at any time has underpinned the adoption at the whole farm scale.

The main outcome aimed for in the course was changed insecticide use, and so the farm practice change model used in the Sustainable Grazing Systems program (Nicholson *et al.* 2003) was applied to the development and implementation of IPM. This model described a continuous three-stage process of motivation, trialling exploration and farm practice change, and recognised the importance of supporting decision making in achieving practice change (Fig. 1).

The initial workshops provided a non-threatening learning environment, which is known to assist in creating motivation to change (Fell 1997). The workshops and in-field training were intended to give growers and agronomists the principles of IPM and then to give enough new information to apply it on the farm.

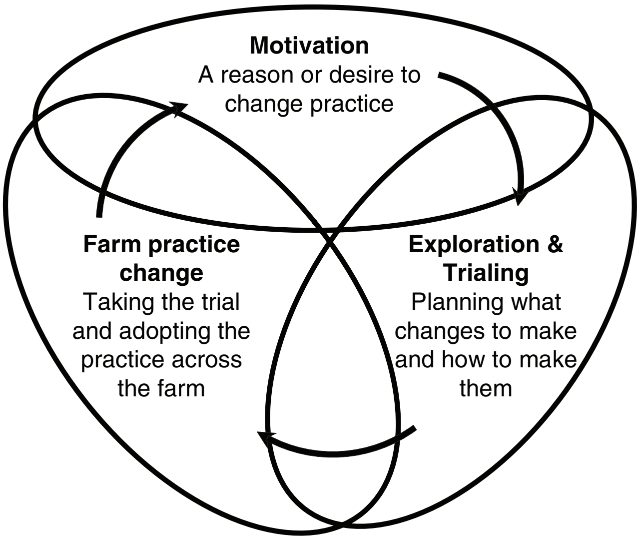

Fig. 1. The three stages of the sustainable grazing systems farm practice change model: motivation, exploration and trialling, and farm practice change.

The course was not a detailed entomological course as it is known that too much detailed information given to farmers can be overwhelming and so deter farmers from attempting IPM (Lynch Greene and Kramer-LeBlanc 1997; Heisswolf and Kaye 2007). Instead, on-going support was available from entomologists whenever needed. All participants (100%) who attended the course understood the concept and were prepared to trial it, and at the end of the season had seen IPM work. That is, they had used naturally occurring biological control agents, had decided on particular cultural controls, and had eliminated the use of broad-spectrum insecticides. Those involved in the course were then, as described by van de Fliert (2003), 'able to make better, informed decisions for location-specific agro-ecosystem management'.

As confidence has grown in the application of IPM, farmers and agronomists have become willing to apply the same principles to more paddocks. For example, it has been reported that since 2006 all insect control decisions for clients across 40 000 ha of crops inspected by one agronomy company have been considered within an IPM context and control recommendations made accordingly (Watson 2007). This company sees that it has a marketing advantage of being able to offer an IPM service. The concept of motivation created by advantage is not new (Frank 1995; Barr and Cary 2000).

Recent studies recognise the significant influence that stress can have on decision making (Shrapnel and Davie 2001; Pannell *et al.* 2006). Any change is stressful, and this includes changing to use IPM. In some cases the potential economic losses were large if the IPM approach did not work, adding to the anxiety not only for the farmer but for those who were advising them. It has been pointed out that until there is confidence in an IPM strategy, a farmer is unlikely to risk 100% of the crop for a possible 10% gain (Trumble 1998). The approach described here gave that confidence to allow adoption. Direct access to entomologists (including mobile phone number) was provided to help minimise the stress felt by farmers and advisors. Many called at key times and the farmers involved have since become strong advocates for IPM.

Changed use of insecticides

A successful implementation of any IPM strategy will require the provision of support for the farmer. In most cases manuals and fact sheets alone cannot provide the support needed; it must come from direct contact with experts. The previous insecticide approach provided peace of mind that all necessary actions to control pests had been taken and so it is up to the IPM experts, as much as possible, to provide the same level of reassurance. On-going entomological support is essential as without this support it is known that interest in IPM falls and the availability of pesticides leads to loss of adoption (Herbert 1995; Sivapragasam 2001; Oka 2003).

The most important result of the process that is described here was changing the attitude that existed: 'spray an insecticide, just in case'. Growers and agronomists involved in the IPM work now know that this can cause problems such as killing beneficial insects and mites and causing secondary pest problems. It is important to note that sublethal effects of insecticides can also be seriously detrimental to populations of beneficial species (Desneux Decourtye and Delpuech 2007) and so those beneficials that survived an insecticide application could still be seriously affected.

There had previously been no consideration that such practices could cause problems with populations of beneficial species. There is a wealth of information in the scientific literature about beneficial species of invertebrates and certainly enough to begin using the knowledge. The approach taken was to apply IPM principles to specific sites, which enabled the basic interactions to be observed without establishing major research trials, as was described by Kemmis and McTaggart (1988). However, the IPM strategies discussed here are seen as just the starting point and there are many opportunities for research to improve them.

Conclusions

There are several points that will conclude this paper, and these are listed below. The results described here are well founded in the scientific literature and deal with the problem of implementing IPM. Herbert (1995) described most of these issues and more than a decade later the same issues are present. The problems are still present but now there are alternative answers present if we want to use them.

(1) There is sufficient entomological information to begin successful IPM in commercial broadacre cropping and to deal with problems as they arise.
(2) The case study outlined here demonstrates a successful approach, consistent with known approaches to IPM adoption, with an unusually rapid rate of adoption compared with overall world trends. The success described requires close collaboration between farmer, agronomist and entomologist advisor.
(3) 'IPM cannot be packaged like seeds' (FAO 2000) and needs to suit the individuals involved. In the case study presented, site-specific advice was given by entomologists direct to farmers and agronomists.
(4) If IPM is complex then it is the role of advisors to interpret the information available and make it simple.

(5) After IPM has been adopted, there is still a requirement for constant collaboration between entomologists, farmers and agronomists to avoid IPM being seen as simply an alternative insecticide program. After IPM for invertebrate pests has been adopted, there is further opportunity to increase the scope to deal with a range of other pests in a holistic approach.

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