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Constraints and solutions for development and uptake of integrated pest management in the UK

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Abstract

Agricultural improvements that reduce conventional pesticide use and support environmental aims are a priority. Current approaches develop promising alternative products but meet significant challenges in bringing them to market. This article reports findings of an Association of Applied Biologists event at which delegates from relevant industry sectors discussed the establishment of an effective integrated pest management innovation system linking multiple stakeholders. Interrelated recommendations were agreed upon, focused on structured gap analysis, co-design processes reflecting the complete innovation system, the approval process, application equipment, enhancing grower confidence, integrating knowledge exchange activities, promulgation of public good information and the need for an overarching national action plan and supporting legislation.

KEYWORDS
biocontrol, innovation system, integrated pest management, regulation

1 | INTRODUCTION

In November 2022, the Association of Applied Biologists (AAB) Biocontrol and Integrated Pest Management (IPM) Specialist Group brought together participants from four different sectors (Figure 1) for a 2-day conference addressing the theme: '*Bringing Biocontrol and IPM to Market*'. The AAB routinely hosts such hybrid events, and this year, 55 in-person and 75 online delegates attended.

The conference provided an opportunity for an in-depth discussion on how to improve innovation in crop protection, particularly the functionality of the 'IPM innovation system'. By this, we mean an innovation ecosystem, as defined by Granstrand and Holgersson (2020), that is, '*the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors*'. In this article, we refer to it as a system rather than an ecosystem to avoid confusion with the natural ecosystem that pests are part of.

This IPM innovation system needs to facilitate the process by which new approaches for pest management are thought of, tested, evaluated and approved to create new products or methods for managing pests. To function effectively, the IPM innovation system should link actors (stakeholders), including academic researchers, industrial researchers, farmers/agronomists and regulators (Figure 1). A strong view that this process was currently not functioning efficiently emerged throughout the meeting, and the objective of this article is to report the agreed views and recommendations regarding essential changes that need to be made to improve functionality. A comprehensive overview of new priority research areas was not an objective of the conference (although it was raised by individual platform speakers in relation to their specialist interests). Thus, this article addresses constraints which are met after the initial research phase,

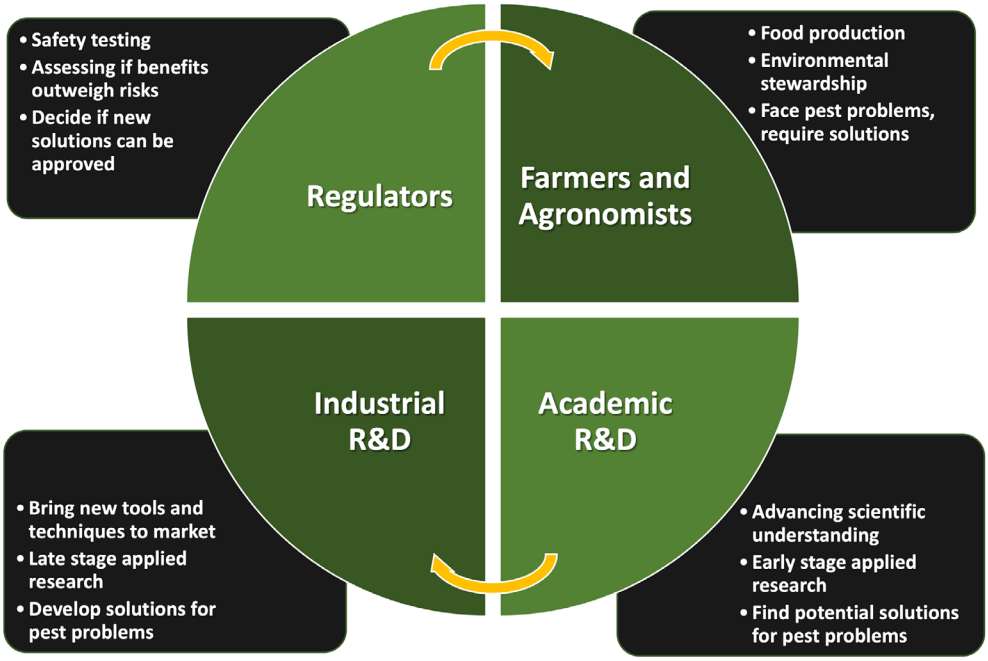

FIGURE 1 Key stakeholders in the crop protection innovation system. Effective innovation and productivity improvement requires communication and coordination between these stakeholders.

which impede the outcomes of this research being taken through to uptake by growers/farmers, and how they can be overcome.

2 | APPROACH

The 130 delegates contributing to discussions at the conference identified themselves as practitioners from four broad sectors. These included Academic R&D (71), Industrial R&D (43), Farmers/Agronomists (7) and Regulators (11).

There were four formal platform sessions, each with titles intended to facilitate input by speakers with a range of (potentially contradictory) views to avoid the risk that conclusions were ultimately dictated by the agenda that had been set in advance. They included Session 1—New Solutions; Session 2—Future-proofing development of sustainable control: gap analysis and innovation; Session 3—Making it work in the field; Session 4—Bringing certainty for business: Comparing/contrasting legislation for biocontrol and IPM around the world. Care was taken when establishing the conference programme that invited speakers would provide a broad overview and introduction to their specialist fields but, like offered presentations, were free to choose their own titles and subject areas. In addition, a poster session was offered in which contributors were also free to present any work relevant to the conference theme.

An important element of the meeting was a final discussion session in which delegates were divided into four break-out groups, each including representatives from all four of the broad sectors defined above, to ensure that a range of perspectives were represented. This encouraged conclusions drawn by each group to be informed by the differing professional experiences and perspectives of the various sector representatives and not solely by the opinions expressed during speaker sessions. The intention was to reach conclusions that balanced the constraints experienced by all contributors, thus providing a single unified view and an agreed basis from which improved implementation and uptake of IPM can be sustainably achieved.

Each group discussed, independently, constraints to the rapid uptake of IPM options and solutions to accelerate translation into practice, reporting their conclusions to an all-delegate discussion at the end of the session. The large degree of overlap of the conclusions emerging from the four groups engendered confidence that the agreed recommendations of the conference were a valid/balanced representation of the views from each sector. With permission of the delegates the conference was recorded, facilitating accurate collation of the conclusions and recommendations.

3 | GAP ANALYSIS: CURRENT SITUATION—REPORTS FROM THE FIELD

To provide a background for discussion of required improvements to the functionality of the IPM innovation system that will promote and support innovation in crop protection, the conference considered ongoing issues facing the UK agricultural and horticultural industries. The industry faces unprecedented pressure to increase yields, whilst simultaneously reducing inputs and reaching climate goals (Baulcombe et al., 2009; Springmann et al., 2018). There is an increasing demand from the government and consumers to use more *'eco-friendly'* farming practices and this has directly impacted how growers can manage plant pests and diseases effectively (Department for the Environment, Food and Rural Affairs [DEFRA], 2023a). Furthermore, climate change is challenging growers with unpredictable growing seasons and new pests, pathogens and weeds, forcing them to face a host of new problems (Christidis et al., 2020).

One of the main issues of concern was the ever-shrinking range of products available to tackle pests (Hillocks, 2012; HSE, 2023). Due to policy changes to reduce unintended consequences and harm that have been translated into legislative changes, many effective active substances (a.s.) used previously to control pests are no longer available, for instance the ban on neonicotinoid based products, or restrictions on dose rates or number of applications per year that have been introduced for others. This is further compounded by the lack of novel conventional chemical plant protection products making it to market, with new a.s. taking more than a decade to develop and subsequently gain approval for use. This may result in overuse of existing a.s., thus increasing the risk of development of resistance to conventional chemical plant protection products over time. Conversely, the loss of conventional chemical plant protection a.s. has been a driver for innovation in alternative approaches to pest and disease management, such as pest and disease-resistant crop varieties, biological control agents, the discovery of previously unknown natural enemies, targeted treatment application to reduce the amounts of conventional chemical plant protection products used, and their integration into tailored IPM systems.

Although there is a clear demand for effective and scientifically robust IPM approaches in agriculture, a lack of cohesion in the industry, specifically between the initial research phase and development to implementation in the field, has resulted in a lack of uptake of many biocontrol and IPM methods. Many research projects are funded for only 2–3 years and securing finance to continue promising research and extension to real-world use is extremely challenging and competitive. This lack of longer-term funding also causes difficulties in providing support for tools designed to help growers implement more sustainable pest management approaches, further limiting their uptake and use. In addition, companies developing biological control organisms are faced with stringent legislation that may not be proportional to the risk posed by the biocontrol agent.

Despite the challenges, the horticulture industry has already seen a relatively wide uptake of IPM and biocontrol products in glasshouse crops. The success in the horticulture sector, coupled with the rise of a 'regenerative' approach in outdoor crops and soaring input costs, has led to increased interest in how to implement biocontrol and IPM practices in broad-acre arable crops. In the United Kingdom, this has been further motivated by recent government Environment Land Management Schemes to encourage farming in a more environmentally sustainable way (DEFRA, 2023b). In addition, the six new standards introduced in the 2023 Sustainable Farming Incentive include benefits for not using insecticides (DEFRA, 2023c). Whether these incentives go far enough remains to be seen, but it is certain that they will not succeed in isolation.

4 | UPDATES ON RECENT DEVELOPMENTS OF IPM TOOLS AND TECHNIQUES

Recent developments in biocontrol and IPM technologies reported at the conference focussed on both new products and increasing the 'smart' application of available control products through better prediction of when and where pests will appear. Ideally, IPM strategies should ensure that treatments are applied at the right time and place to disrupt pest population growth and life cycles. At the AAB meeting, various projects developing predictive strategies to help manage pests illustrated the potential of broad-acre crops. For example, work was ongoing in developing a decision-support tool using knowledge of environmental factors, crop growth and disease development stages to determine the risk posed by barley yellow dwarf virus, which can cause an 80% reduction in barley yield. The recent ban on neonicotinoid seed treatments has limited farmers to the use of foliar pyrethroid treatments to tackle the aphid virus vector, and the planning tool might lead to reduced incidence of aphid resistance to pyrethroid insecticides (AHDB, 2023).

Second, a model was introduced that explored the efficacy of the botanical bioprotectant Azatin (the only azadirachtin-containing product available in the United Kingdom) against the peach-potato aphid, *Myzus persicae*, on sweet pepper. Although the model predicted complete aphid eradication, the subsequent glasshouse trials showed that some aphids were able to survive. This research highlighted the challenge of developing effective models, and the importance of empirical testing when dealing with complex multifactor interactions.

Research aimed at developing macrobiologicals was also advancing, as illustrated by recent success in overcoming the challenge of moving from laboratory to field with the use of the endophytic fungus *Epicoccum nigrum* for control of apple canker (Papp-Rupar et al., 2023). Other examples included industry-funded research into the development of the low-temperature-active brown lacewing *Micromus angulatus* as an effective aphidophagous predator across a range of crops. However, when discussing such advances, the significant challenges encountered when appropriate permissions for the release of macrobiologicals into the natural environment were sought were frequently raised. Such releases are addressed by the DEFRA Advisory Committee on Releases to the Environment, and do not need to go through procedures defined by legislation relating to safe development and use of Plant Protection Products. Thus, it was encouraging to learn about recent releases of three non-native species to tackle the invasive plants *Crassula helmsii* (Australian swamp stonecrop), *Impatiens glandulifera* (Himalayan Balsam) and Floating Pennywort (CABI, 2023). It was noted in the discussion that, whilst recognising the need to carefully assess the potential for and avoidance of detrimental environmental effects, the required legislatory processes should be designed to ensure this is done efficiently and unnecessarily long time scales required to achieve approvals are avoided.

The use of semiochemicals (naturally occurring or synthesised compounds that modify the behaviour or physiology of insects) in IPM is another growing area, offering an alternative to conventional chemical plant protection products. Success in this field was illustrated by the effective use of a 'push–pull' system (Cook et al., 2007), employing a semiochemical to reduce the impact of the European tarnished plant bug (*Lygus rugulipennis*) in both strawberry and cane fruits (Fountain et al., 2021). It was agreed that semiochemicals will continue to be a central tool in future IPM strategies, and the development of

such systems should be supported by the involvement of all sectors represented at the meeting (Figure 1).

Thus, the conference outlined a range of new initiatives, illustrating the potential emerging from current research. Recognising that a notable proportion of such initiatives do not translate to commercial use, however, discussions reflected a series of issues that detrimentally affect the development and uptake of IPM approaches, with associated recommendations to start addressing them.

5 | STRATEGIES TO IMPROVE THE UK REGULATORY ENVIRONMENT

Ideally, good legislation ensures compliance with societal, safety and environmental requirements, facilitates a strong and profitable plant protection and production industry, and encourages innovation. The conference heard from the UK DEFRA on plans for regulatory reform and support for biopesticide approvals. There was strong agreement with the fundamental pillars of UK and EU regulation, in that products must be safe for people, for the environment and efficacious for farmers and growers. However, concerns were expressed that the current UK regulatory system did not help to ensure that farmers and growers had sufficient tools available to implement effective and sustainable IPM practices in this time of rapid change. Moreover, due to the high costs of approval specifically for the United Kingdom, unknown and potentially long timelines and unclear processes, the current regulatory system can act to impede or delay innovation, and these concerns should be considered when the new legislation is developed. Producers of biopesticides and other plant protection products currently saw the United Kingdom as a small market with regulatory processes causing high barriers to entry. For UK agriculture and horticulture to remain competitive, these barriers must be addressed.

Alternative approaches taken in the EU and in the USA were discussed. For example, a description of the USA IR4 project, set up in the 1960s to ensure that speciality growers have access to low risk and effective pest and disease controls, impressed delegates with what was thought to be its pragmatic approach. They thought that it harnessed government support to make it more likely that US agriculture and horticulture had the tools required to be successful. Although recognising that UK legislation must address the specific characteristics of the country's horticultural and agricultural industries, an equivalent focus on supporting the provision of low risk and effective alternative products and tools as rapidly as possible is important.

Potential components of an overall UK approach were discussed, such as allowing the use of trial data generated to EPPO/OECD standards in other countries to be submitted for UK regulatory approval. In addition, taking a permissive approach to the use of a.s. and products that reflect those already used in central zone EU nations (where agronomic practices and environmental conditions are largely comparable) offers a potential way forward. It was generally agreed that such approaches could be central to ensuring that UK farmers and growers were not left behind during the adoption of IPM practices across other regions.

The conference recognised that farmers and growers wish to produce sustainable, high-quality produce, but they need to have the tools to do so profitably. Whilst we should not lower the standards of the UK regulation system, it is important to remove other existing barriers to entering the marketplace. Innovation requires support, and regulation in the United Kingdom must reflect the realities of the marketplace and the needs of an industry that is facing a great number of challenges.

6 | CONSTRAINTS TO THE RAPID UPTAKE OF IPM OPTIONS—RECOMMENDATIONS

Facilitating the uptake of IPM options was a recurring theme returned to by speakers throughout the conference and became the main focus of the lively and productive group discussion session involving participants with a diversity of experiences. The objective of this session was to identify major factors that deter the adoption of new pest control options when they become available and make recommendations for what can be done to overcome them.

6.1 | Structured gap analysis

The provision of practical options to farmers that address *real* and immediate issues faced by the industry was identified as an urgent priority. Several examples of pest, disease and weed targets, for which appropriate tools and techniques for management are not available, were discussed at the conference and it was agreed that research to address these and future gaps is urgently required. This work should not be limited to the development of new tools but also include more innovative ways of using both new and existing tools, to meet sustainability goals and still achieve high levels of crop quality and yield.

It was proposed that this effort should be supported by a formal, structured and ongoing gap-analysis process. This should be regularly updated to account for gaps being filled or new gaps that appear when existing pest management products are lost or new tools are developed. An analysis of biopesticide products for use in integrated vegetable production was commissioned by AHDB in 2009 and provided an illustration of what was needed (Gwynn, 2009). It should be updated and extended to cover all relevant sectors to provide a comprehensive baseline for an ongoing effort. If conducted on a national scale and involving all industry sectors identified in Figure 1, this would identify agreed priority targets for research and development on an ongoing basis, facilitate industry involvement at the earliest stage, inform legislators of current thinking and assist decision-making by funding bodies.

6.2 | Co-design process

The development of such approaches/tools, however, was thought to be insufficient on its own as it will not address the problem of limited transition from basic research into grower/farmer practice. There was

a broad agreement amongst industry representatives that information emerging from academia, at times (not always), delivers a scientifically sound basis for conclusions about problems relating to pest and disease management but would benefit from being better aligned to specific real-world challenges. Currently, commissioned work often focuses on academic research yielding outcomes that are too far from commercial implementation, resulting in delays to practical solutions being available. Furthermore, good initiatives sometimes flounder because of the cost and time required for essential developmental research to convert outcomes of the initial research phase into practical options that can be integrated into reliable/cost-effective commercial IPM practice. A consensus emerged that the involvement of practitioners (farmers and agronomists) in a co-design process from the initial conception/proposal stage of projects would provide a two-way dialogue that facilitates full recognition/integration of commercial constraints from the initial planning stage. This would allow good accounts to be taken of such constraints and opportunities at the initial design phase of the experimental work, facilitating the emergence of more practical outcomes and reducing the amount of unnecessary or late-stage development required.

6.3 | Complete innovation system

In the discussion, examples where co-design was already being practised were raised. For example, the British On-Farm Innovation Network offers a forum within which farmers, consultants, service and equipment providers and academics aim to work collaboratively on projects from first inception and through delivery to final release for industry use (bofin.org.uk). It was agreed that wider adoption of such approaches would be beneficial in maximising return on investment. However, such a strategy was thought to be insufficient in some cases, as the development of pest and disease management options also needs to consider the complete IPM innovation system (Figure 1), including regulatory authorities, as effective delivery onto the market of new plant protection products requires plant protection regulatory approval. Knowledge and understanding of a clearly defined approval process are needed by researchers if they are to develop the required products efficiently. Some of the constraints imposed by a stepwise approach (Research/Development/Approval, etc.) would be overcome by ensuring that the early research work conducted reflects/anticipates the needs of each stage, potentially avoiding non-viable options being explored.

6.4 | Clearly defined approval processes

In support of the recommendation in Section 6.3, the conference identified the urgent need for legislators to provide clearly defined approval procedures and requirements for biological control products, as lack of clarity about such processes was currently thought to be a serious constraint in this area. Ultimately, the aim of many applied research projects is to develop low-risk plant protection products, but it should not be overlooked that their use is often not entirely without risk. Thus, care must be taken to ensure that approval processes incorporate and reflect cost-efficient but robust approaches to identifying, minimising and mitigating any risks posed. Currently, conventional chemical plant protection products in the United Kingdom are subject to stringent legislative processes and requirements, which have progressively evolved over many years. More recently the requirements for non-conventional alternatives have been developed, but can present a difficult, time-consuming and expensive process to achieve registration as plant protection products. Making the process of registration simpler and having an effective and proportional approach to the assessment of the risk posed by the beneficial organism would represent a significant contribution to supporting the use of IPM in commercial practice.

6.5 | Application equipment

Other needs that should be considered in relation to the future development of more sustainable pest management options were touched upon and are worth noting. New options using biological control agents often require the use of new or modified application techniques or equipment. The inclusion of equipment manufacturers in development project teams may often be beneficial, as demonstrating effective suppression of pest/disease/weed problems alone may not be sufficient. It is often overlooked that effective application is essential to commercial viability and can often enhance impact.

6.6 | Grower confidence

Current public and government focus on achieving high yields of high quality produce (to be marketed at low cost) in an environmentally and economically sustainable way, adds to the imperative of increasing the number and rate at which user-ready alternative management options become available. There is evidence that to compete with imports produced to different standards, effective, lower cost options are urgently required, and the lack of sufficient alternatives is currently adding to economic pressures, which may result in UK producers becoming increasingly uncompetitive. Promptly addressing the above issues is important if the UK plant production industry is to achieve the objective of sustainable production, and will also support subsequent uptake by making approaches farm-ready. Conducting some of the basic work on commercial farms with close farmer involvement (as an important adjunct to demonstration farms which promulgate findings) will provide data which may appear to be more relevant to farm businesses and allay the understandable concerns regarding the perceived risks and costs of being amongst the first to adopt a new method.

6.7 | Greater integration of knowledge exchange activities

A key element in the transition of new management options from research to commercial application is the knowledge exchange

component of the IPM innovation system (Figure 1). The move towards more sustainable farming methods will be accelerated by a comprehensive and readily accessible suite of actions in this area. It was broadly agreed that a range of effective approaches are available currently, but greater integration and, in some cases, wider availability would improve their efficacy. One speaker provided an overview of a successful knowledge exchange approach for the effective suppression of Asian Citrus Psyllid with pink-coloured kaolin clay (Pierre et al., 2021). Lessons learnt from this experience indicated that a more targeted effort to inform potential early adopters is needed, as they are a key route to educating other growers about the strengths and drawbacks of new approaches and the economic impact on farm or horticultural businesses.

Further discussion suggested that careful selection of targeted dissemination methods can be key to the future roll-out of new options. Efficient routes included demonstration on strategic farms, inclusion in professional training and provision of bespoke decision-support tools (Rose et al., 2016). More novel ideas included the establishment of farm-to-farm engagement hubs through which information and first-hand experience could be shared and discussed. Such hubs may also offer a learning platform for academia as valuable feedback could be gathered to inform future work. The key was, however, to carefully design a comprehensive strategy which incorporates a range of such approaches specifically selected to meet the characteristics of each case, rather than following a one-size-fits-all method. Such integration reinforces the information provided but is often overlooked, particularly among academics.

6.8 | Promulgating 'public good' information

Where new options are not specific products (i.e., owned by particular commercial businesses), but instead are approaches that are the product of 'public good research' which can be made available openly and without charge, funding for advice and promotion is usually difficult to obtain. It was agreed that for these, and other areas, wider consideration and an effective solution regarding how to promulgate such information is needed. Finally, funding opportunities that encourage translational research alongside research into the methodology, specifically involving appropriate industry sectors (e.g., farmers, consultants, manufacturers, etc.), are important if uptake is to be encouraged.

6.9 | National Action Plan

The uptake of IPM methods would be strongly facilitated by improved cross-sector coordination, with associated strategic planning (Figure 1). A much greater focus and discussion of the value chain (the full lifecycle of a product or process, including material sourcing, production, consumption and disposal/recycling processes) would provide more convincing sustainability arguments than the current, more limited focus, which emphasises environmental issues. Moreover, well-coordinated and targeted events or meetings linking academia, advisors and consultants, legislators, and commercial industry (including growers), would promote engagement to ensure that practical and profitable ideas that make economic sense for growers and farmers are researched. Where commercial constraints permit, improved data and information sharing about products and approaches would increase the rate at which new management options appear.

Overall, it was felt that an improved rate of development and uptake of IPM approaches would be more effectively achieved under a National Action Plan that integrates and coordinates the above recommendations. This would provide a platform on which industry members, academics and regulators could be assembled to discuss/develop solutions to the major existing and future pest management problems. Ultimately, it would also focus on the effective deployment of available funds, resulting in more projects/programmes yielding practical management solutions and supporting end-user industry uptake.

7 | CONCLUSION

Discussion at the conference was characterised by two general themes, positivity surrounding the development of control agents, methodology and predictive tools to aid the development of IPM strategies, but concerns relating to constraints associated with bringing them through to commercial use. There was a high level of agreement between sectors regarding recommendations to improve the latter, including the following:

1. *Legislation*: Innovation requires support, and regulation in the United Kingdom must reflect the realities of the marketplace and the needs of an industry that is facing a great number of challenges, whilst not lowering the current standards.
2. *Structured gap analysis*: A continually updated and structured formal gap analysis conducted on a national scale is needed, involving input from legislators, industry, academia and growers/agronomists, which is regularly updated to identify new gaps as they arise.
3. *Co-design process*: Involvement of farmers/agronomists in a co-design process from the initial concept/proposal stage, and continuing throughout the delivery phase of research, generating new control options, thus facilitating recognition/integration of commercial constraints.
4. *Complete innovation system*: The co-design process also needs to consider the complete IPM innovation system (Figure 1), including regulatory authorities, as effective delivery onto the market of new plant protection products requires plant protection regulatory approval.
5. *Clearly defined approval processes*: Development of clearly defined approval procedures and requirements for biological control products that provide a simplified, effective and proportional approach to assessment of the risk posed by the beneficial organism is needed.
6. *Application equipment*: Where new application techniques or equipment are needed in support of new control options,

inclusion (from the very beginning of research projects) of equipment manufacturers in the project teams addressing the development of such options is important.

7. *Grower confidence*: Grower concerns about reliability, efficacy, cost-effectiveness and other considerations affect uptake of new control options. Involvement of farmers through a co-design approach and conducting basic research on commercial farms with close farmer involvement, would provide data that appears to be more relevant to farm businesses and would represent an important adjunct to demonstration farms to promulgate findings.
8. *Greater integration of knowledge exchange activities*: Improved uptake of new pest management options would result from better integration of the knowledge exchange component of the IPM innovation system. An expanded and readily accessible suite of actions might be established and supported, from which a subset is selected and incorporated into a comprehensive strategy tailored for each research programme that aims to develop new pest management approaches.
9. *Promulgating 'public good' information*: Pest management options emerging from 'public good research' can be made available openly and without charge, but funding for advice or promotion is usually difficult to obtain. An effective solution regarding how to promulgate such information is needed.
10. *National Action Plan*: The various routes to an improved rate of development and uptake of IPM approaches described above would be more effectively achieved if coordinated under a National Action Plan.

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