Integrated pest management, semiochemicals and microbial pest-control agents in Latin American agriculture

Luis C. Rodríguez, Hermann M. Niemeyer*

Departamento de Ciencias Ecológicas, Facultad de Ciencias, Universidad de Chile, Casilla 653, Santiago, Chile

Abstract

Some selected issues regarding integrated pest management (IPM) development and adoption in Latin America are explored in relation to the characteristics of Latin American farmers, and the strategies of donors and practitioners for IPM research and development. The challenge is facing the complexity of IPM and the extensive presumptions regarding the farmer's problems and needs. Emphasis is on IPM practices involving semiochemicals and microbial pest-control agents, which are reviewed from a Latin American perspective both for the market of IPM products, and the regulatory directives for registration and use of semiochemicals. Finally, IPM research in Latin America is reviewed.

Keywords: IPM; Latin America; Semiochemicals; Microbial antagonists; Pesticides

Contents

*Corresponding author. Tel.: +56 2 678 7409; fax: +56 2 6787445.
E-mail address: niemeyer@abulafia.ciencias.uchile.cl (H.M. Niemeyer).

1. Introduction

Kogan (1998) defined integrated pest management (IPM) as a decision support system for the selection and use of pest control tactics, singly or harmoniously coordinated into a management strategy, based on cost/benefit analyses that take into account the interests of and impacts on producers, society, and the environment. This definition inherently considers the existence of ecological and economic thresholds, the need to adopt the socio-ecosystem as a management unit, the existence of a broad number of IPM tools including the rational use of chemical pesticides, and the requirement for interdisciplinary systems approach, particularly since certain control measures may produce unexpected and undesirable effects. As such, IPM requires the co-ordinated inputs from diverse fields of expertise to develop tools that can be adopted as IPM practices.

In developed countries, maximisation of crop production is no longer a priority since consolidation of farms into larger units, high-input/low-labour agricultural systems, and huge increase in crop yields as a consequence of the green revolution of the 1970s, have led to food surpluses. In these countries, the adoption of IPM is usually associated with increasing public concern about the negative effect of pesticides on consumer health and on the environment, particularly regarding the capacity of natural systems to provide ecosystem goods and services that contribute to people's well-being. On the other hand, in developing countries, a myriad of different agricultural systems are currently in operation. These range from subsistence agriculture in common property lands, where some IPM practices, such as intercropping or crop rotation, are usually employed as part of traditional cultural procedures, to large highly mechanised estates that produce crops for export. The latter employ IPM practices in order to comply with regulations of importing countries (see Amador et al., 2002). Several criteria may be used to categorise these agricultural systems and to define the need for IPM practices and their potential level of adoption. Among them are: differences in crop value and crop diversity, market accessibility, wage/family labour availability, aim of the adoption of IPM i.e. profit maximisation or risk avoidance, access to modern technology, level of recognition of traditional knowledge, level of external support, capability of producers to develop research or to receive extension support, and ability of producers to incorporate changes based on reasons other than previous empirical experience. Some of these criteria with particular emphasis on agricultural systems from developed and developing countries have been adequately and extensively reviewed elsewhere (e.g., Way and van Emden, 2000).

In Latin America, some general issues have been identified regarding the obstacles for the success of IPM programs. These include insufficient technical knowledge with only a few active IPM researchers, poor infrastructure in both research and extension systems, a weak public sector that limits the dissemination of information and provides inappropriate credit and subsidy schemes, and the influence of agrochemical companies on governments and their agencies (e.g. Bentley and Andrews, 1996). This article explores other selected issues related to the role of IPM in Latin America, particularly those involving semiochemicals and microbial antagonists, and then discusses the current situation of IPM research in the region.

2. Integrated pest management issues

2.1. Top-down vs. bottom-up IPM research and development

IPM practitioners commonly follow a top–down scheme of research and development that goes from scientist and managers to peasants. This approach identifies a pest problem, develops an adequate IPM practice to solve it, and transfers the practice to farmers. A recognised successful case is the biological control of cereal aphids in Chile by the introduction of hymenopteran parasitoids (Zuñiga, 1990). Alternatively, the "farmer first" approach follows a bottom–up scheme which identifies gaps in farmers' knowledge and supplies the missing information to farmers, who finally develop their own solutions, hence adapting IPM to their needs. An example of this are the farmers field schools in Asia, a model whose transfer to locations in Latin America has been promoted (Brawn et al., 2000). In many cases the inadequate levels of peasant's knowledge as well as the high cost of farmers training and scaling-up participation make this approach unfeasible (Morse and Buhler, 1997).

We consider that in many places in Latin America, discussions regarding whether 'the paradigm of IPM' overlays the 'farmers first paradigm' or vice versa, are of secondary importance. There is a chronic lack of funds and scientists available to address at least a few of the hundreds of already identified problems potentially to be solved by IPM practices in a conventional top–down approach. Additionally, many of the successful IPM projects point to the importance of peasant participation and involve a strengthening of their traditional agricultural systems. Thus, IPM practices such as intercropping, crop rotation, or use of resistant cultivars are commonly employed by farmers without been tagged as IPM actions, and further traditional pest control practices among Latin American peasants are constantly being identified as continued and extensive fieldwork takes place (e.g., Morales and Perfecto, 2000).

Some IPM practices, which strengthen peasants' productive capacity and consider the socio-ecosystem as a management unit, are being adopted as a consequence of development projects. In Bolivia, a project among Aymara communities improved the living condition of poor peasants by increasing crop yields using IPM practices and at the same time restored and improved pasturelands. Additionally, it allowed a stronger participation of women in livestock activities, thus increasing their influence in the decision-making processes within the family (CODECO, 2001). In Cajamarca, Peru, a project involving IPM practices and agro-forestry diminished the local dependence on external inputs, improved the role of traditional institutions, and increased peasants' income, thereby enhancing their degree of capitalisation and avoiding seasonal migration. This successful project inspired other contiguous communities to initiate their own programs and to adopt the methodology (CIED, 2001). In Colombia, some IPM practices were transferred to inhabitants of a watershed affected by deforestation for paper production. The project involved the rescue and adoption of traditional farming systems complemented with agroforestry activities, in an area where most people belong to poor black communities. As a result, peasants obtained food security and lowered the pressure on remaining forested areas. Additionally, the increased networking among farmers led them to create a black community council, aiding community organisation, promoting responsible management of communal resources, and avoiding cultural erosion (cf. Scialabba and Hattam, 2002). These examples of Latin American experiences show that IPM approaches that promote practical, realistic, economic, and achievable solutions—particularly those which incorporate spatial and temporal variability, feasible objectives, and systematisation and validation of peasants' knowledge in order to effectively complement scientific information—might provide enough expertise and adaptability to represent a shortcut from long term and costly research, and will allow the re-allocation of funds to more urgent research lines or to enhance the social institutions and the extension system in order to properly diffuse the information to potential users and hence to accomplish IPM goals.

2.2. *Complexity of IPM*

The inherent complexity of IPM has sometimes been pointed out as a factor limiting its adoption (Grieshop et al., 1988). Contrary to common assumption, IPM complexity represents a challenge for farmers all around the world and not only in developing countries where the farmers' education level is expected to be lower than in developed countries. One example that illustrates this point is the problem of adoption of thresholds by peasants. Orr (2003), considers that one fundamental IPM concept—the economic threshold—has proved too complicated for resource-poor farmers to implement, and provides some examples that relate to unsuccessful implementation with education variables such as literacy and numeracy. Nevertheless, in developed countries, such as the UK, the adoption of these economic thresholds is also not prevalent (Morse and Buhler, 1997). In other words, neither resource poor farmers nor developed country farmers are able to adopt an economic threshold approach for IPM due to its complexity, and in practice, IPM practitioners often need to provide solutions that represent intermediate points between strategic and purely tactical IPM forms.

2.3. *Farmers' problems and needs*

The previous example may also serve to illustrate the capacity of IPM to adapt solutions to different farmers based on their needs. In the UK, a solution represents the adoption of fixed thresholds because in spite of their inefficiency, they are good enough for most British farmers as a point to determine the need of a control measure. In many developing countries, farmers often develop their own thresholds, based on empirical knowledge not easy to code (Stonehouse, 1995), and IPM practitioners frequently prefer more simple thresholds based on "eye-balling" the fields rather than highly elaborated and hence inapplicable ones.

A widespread presumption of donors and foreign extension workers is to consider that crop losses from pests represent the main production problem facing smallholders and consequently there is a bias towards biological control and resistance breeding issues over other IPM methods. Nevertheless, in Latin America peasants often manifest the existence of low pest problems (e.g., Morales and Perfecto, 2000), while expressing their concern for progressive crop yield reduction due to declining soil fertility or changes in hydrological regime. Consequently, investment in pest control will be relevant only if it can be shown that losses from pests represent an important production constraint relative to other factors such as soil fertility, and if it provides a higher return than investments to improve other production constraints. Hence, a very close participative relation between IPM researchers/extensionists and farmers will be required to deal with unexpected and undesirable results and to develop adequate practices that fulfill farmer needs. This is specially relevant since it is well known that Latin American peasants do not commit themselves to projects that do not apply their priorities (Bentley and Andrews, 1996).

The three previous issues suggest that IPM focus should be shifted to what is achievable under the farmers' circumstances rather than on what is currently considered technically perfect. Enormous differences between big agricultural and forest companies, which produce for export, and small holding peasants who practice subsistence agriculture, are evident in their capacity for solving problems and accessing all potential methods for pest management. In many cases exporters are able to allocate financial resources to provide solutions to their needs by developing research or importing and adapting the required technologies; however, small holders are mainly dependent on the external aid provided by extensionists and the particular type of IPM tool/practice they promote (Farrington and Bebbington, 1991). This is not surprising, since much of the extension labour in Latin America occurs as part of projects funded by donor agencies with specific goals and methodologies. The rationale behind the choice of projects is that they ensure the best return for the invested money; however, this approach limits the scope of existing IPM practices, which may be extended to farmers, and may bias IPM research towards more extensible and fundable practices.

3. Semiochemicals and microbial antagonists in IPM

3.1. General considerations

Semiochemicals, i.e. molecules involved in chemical communication within and between species; and microbial antagonists, i.e. entomopathogenic organisms employed for pest control, seem to be among the least extensible IPM practices for small holder peasants. Comprehensive reviews of the classification and use of semiochemicals and microbial antagonists are available (e.g., Shani, 2000; Lacey et al., 2001). The most important attribute of both semiochemicals and microbial antagonists for IPM is their specificity, since most of them are bioactive towards only certain species or groups of insect pests. This could represent a problem when used against pest complexes. In general, their disadvantages are mostly linked with their low persistence and potential to provide long-term control as their use needs to be complemented with other control methods. The low speed of kill by microbial antagonists and the high cost of both practices are also perceived to be a problem, although their cost compared with conventional control measures such as chemical pesticides is not prohibitive if environmental benefits, such as safety for humans and other non-target organisms, reduction of pesticide residues in food, increased activity of natural enemies, and increased biodiversity in managed ecosystems are taken into account. However, the market rarely reflects these benefits. Paradoxically, the fraction of the cost corresponding to royalties for the use of patented semiochemicals or microbial antagonists is usually very high and in many cases the cost of access to these technologies is higher than the savings in pesticides (e.g., Kelly et al., 2003). In the last few years the production cost of semiochemicals and microbial antagonists has decreased, but they are still unaffordable by most Latin American farmers. Some efforts have been directed towards the development of reliable controlled-release technologies for semiochemicals notably increasing their efficiency and allowing their inclusion in many operational IPM programs (e.g., Clarke, 2001). These programs have illustrated the preventive, predictive, and control capabilities of semiochemicals. Although semiochemicals are not biocides by themselves, their control capabilities are evident by their capacity to generate behavioral changes such as epideictic, aggregation or mating disruption, or to lure and kill by the association of attractive semiochemicals with chemical pesticides or entomopathogenic organisms.

Microbial antagonists are biocides. They may normally exist in nature and their prevalence anthropically increased, or may be introduced into pest populations by inundative releases with the aim of controlling pests before certain thresholds are surpassed. These control releases are frequently performed using formulated products prepared from microbial isolates (e.g., insecticidal proteins) of naturally occurring or conjugated strains. However, microbial antagonists are also important in prevention, by minimising the effects of insect infestations within a location through the incorporation of the genes responsible for production of the toxin into the crop plant genome.

3.2. Semiochemicals and microbial antagonists in IPM practises in Latin America

IPM practice in Latin America is difficult in subsistence farming, where even a low cost off-farm input can render the whole operation economically unjustified. Pheromones and microbial antagonists may be relatively expensive and their cost may represent a substantial proportion of or even exceed the value of the crop they are to protect. Results can be obtained only if the crop has sufficient value and yield potential such as in peri-urban horticulture or in large plantations producing crops for export. Thus, in Costa Rica pheromone traps have been used for control of several palm pests on account of the high export price of palmito (Alpízar et al., 1997). A different situation occurs in Argentina, where walnut farmers lose about 50% of their production due to attack by several walnut moths. The massive use of chemical pesticides has generated insect resistance, and the presence of residues has limited exports. A control program involving pheromones was effective in diminishing the use of pesticide and lowering residues. Nevertheless, the cost of pheromones was prohibitive and now researchers are evaluating other IPM practices, such as biological control (Fidalgo and Torrens, 2004), while the Argentinean government has exempted taxes to the importation of the required semiochemicals. Another example is among Peruvian cotton growers who use *Bacillus thuringiensis* and pheromones, while Peruvian subsistence farmers exhibit relatively little use of off-farm inputs, except when a transient development project or government scheme significantly subsidises the cost (Lizarraga and Ianncone, 1996). This contrasting situation is common in Latin America, and naturally donor agencies are more concerned with the second group of farmers. Nevertheless, experience dictates that once the external support is terminated, the recommended practices are no longer feasible due to their high real cost, and the lack of continuous product supply. Thus, these practices are extremely dependent on external supplies as compared with other IPM practices such as cultural procedures. This was illustrated in a project developed by the International Potato Center in Peru among small farmers using pheromone traps to control post-harvest losses from the potato weevil, which although technically successful, was unsustainable when the funds became scarce (Schafer and Thrupp, 1996). Moreover, peasants often abandon a practice because of the arrival of a new project in the area sponsored by another agency with different goals. They get enrolled on the new project mainly to have access to external assistance, e.g. micro-credit access, technical support, or market advice. Considering the importance of economics in the adoption and development of semiochemical and microbial antagonists, two important issues are briefly highlighted relative to their market and regulations.

3.3. Use and production of semiochemicals and microbial antagonists in Latin America

Despite intense technical and scientific efforts for IPM diffusion, IPM farming still remains insignificant in Latin America. Uruguay has the highest percentage area of cultivated land solely under IPM practices (4%), almost double that in Costa Rica (2%), Argentina (1.9%) or Chile (1.5%), and many times higher than in Mexico (0.13%) or Brazil (0.08%). The current Latin American share of the world market of bio-pesticides is about 9%, but it is expected to significantly increase due to their promotion, local manufacture, and the increase in organic crop production in the region (Jones, 2001).

In spite of the attained levels and expected growth of IPM products, manufacturers are not able to develop markets by themselves in competition with agrochemical companies. In Latin America, there are several companies devoted to the production of bio-pesticides, mainly entomopathogenic fungi and microbial antagonists, but only few manufacturing semiochemicals. Thus, in Colombia there are about a dozen companies mainly focused on commercial production of fungi toward pests of export products, such as coffee and flowers. Some of these companies have been producing bio-pesticides including microbial antagonists for 25 years, and currently comply with the most exigent international certifications. In Brazil, microbial antagonists, entomopathogenic fungi and baculovirus producers have been working for 30 years in the control of strategic pests and their current prices are very competitive due to their large production volumes. In smaller countries such as Nicaragua there are also a few bio-pesticide manufacturers mostly centered in the control of fruit and sugar cane pests, although their production capacities are modest. The same applies to the Paraguayan manufacturers of fungi and microbial antagonists who, due to their small size and high financial risk, often operate as limited liability companies. In Chile, the producers are small biotechnology companies focused on developing products to solve local problems, and in order to reduce financial risk and to increase their portfolio of products they are also distributors of foreign firms. In Honduras, most manufacturers of fungi and microbial antagonists are dependent on large local institutions dedicated to education and production, or are subsidiaries of foreign companies. In Costa Rica, there are about six producers of biological agents, and through training provided at the national specialised center in organic agriculture (INA), about 20 home laboratories have been created. These laboratories are provided with biological strains and they base their production in solid substrate methodologies, which suffer losses between 20% and 30% due to contamination and temperature problems. Sometimes, the production costs are higher than the price of chemical pesticides. In Cuba, there are over 200 such laboratories and 3 industrial manufacturers dedicated to the production of microbial antagonists and entomopathogenic fungi. Cuban production of biological agents has significantly increased from about 1700 tons per year in the early 1990s to about 2500 tons in 2002, mainly as a consequence of a national policy to promote organic agriculture systems derived from the severe drop of pesticides and fertiliser imports from the former USSR.

The production of semiochemicals in Latin America is less widespread. Some allomones are produced in Mexico, several Brazilian companies produce pheromone traps and pheromone microcapsules mainly for protection of temperate crops of southern Brazil (FEROBIO, 2002), and in Central America a Costa Rican company is currently manufacturing pheromone traps for about 36 different insect species that are regional pests.

The incipient Latin American industry of semiochemicals and bio-control agents, due to their small size, is generally lacking satisfactory scaling up procedures and quality control. The high costs of producing these agents compared with the price of generic chemical pesticides represent a high financial risk for investors. Their limited supply, as well as the lack of advanced knowledge by government extension staff, has restricted their adoption by farmers. Furthermore, producers of semiochemicals and bio-control agents underline the importance of clear and coherent legislation for the progress of the industry, and in consequence enormous efforts are still needed from the public sector regarding promotion and regulatory issues in many parts of Latin America.

3.4. Regulatory directives and the irregular situation of semiochemicals: an unprotected market for crop protection

The previous section highlighted the financial vulnerability of the IPM products industry. Many IPM manufacturers consider that they are unprotected because regulatory directives force them to compete directly with chemical industries instead of having separate systems for registering plant protection and pest management products. These directives are greatly influenced by the experience of regulators dealing with the chemical pesticides industries and it is not uncommon that many of the regulations for control products other than chemical pesticides are the same as, or at best extrapolated from, those developed for chemicals (Neale, 2000). In many countries, semiochemicals, by the fact of being chemicals, have been incorporated into the class of chemical pesticides, and are subjected to their same regulatory directives, in spite of not being biocides. Lately, these regulations are being relaxed: for example, semiochemicals must be registered in the USA only if used for disruption or attract/kill strategies, but not for monitoring/surveying, mass trapping, or kairomone use (Weatherston, 2004). The registration procedure is still considered too expensive to be viable. Few manufacturers are able to provide a full registration dossier, since the registration cost for semiochemicals is between US$ 0.3 and 0.5 million, representing about 40% of the expected revenues, while for chemical pesticides a similar cost signifies only 1% of expected revenues. The number of semiochemicals whose structures are known is high, but only an extremely small percentage of these materials will ever be considered for commercialisation (Birkett and Pickett, 2003). The registration of a microorganism is still more expensive, with costs over 1 US$ million (Blum, 2002). This registration procedure may constrain the research on and development of new products and only a small percentage of those will be able to complete the registration procedure.

In most Latin American countries the decision to approve a pest control product is based on the demonstration that the product is efficacious, and that it complies with the local norms of human health and the environment. In the Comunidad Andina (Venezuela, Colombia, Ecuador, Peru and Bolivia), norm 630 regarding the registration and control of chemical pesticides does not consider pheromones and entomopathogenic microorganisms among chemical pesticides, and their registration procedures are different (Comunidad Andina, 2002). In Peru, the promotion of IPM is considered a national strategy since 2000, and some reforms have reinforced the functions of the public institutions involved such as the National Committee of Pesticides and the National Service of Crop Health. At the same time, the National Committee for IPM was created. Earlier the Peruvian promotion of IPM included an adequate legal frame, so that pheromones were explicitly removed from the definition of agricultural pesticides, a definition of attractant was incorporated, and pheromones were classified under a different category with different requirements regarding their registration (Republica del Perú, 2000). In Chile, a norm of 1999 regarding the evaluation and authorisation of pesticides considers pheromones in the same category as chemical pesticides and are subject to the same regulations for their registration. The use of pesticides is regulated by law and only products registered in Chile are permitted, in the doses and recommendations printed in the container. Consequently, many farmers employ these norms for local products and more strict foreign norms to comply with export requirements, thus differentiating among consumers. The Brazilian federal law of agro-toxics and similar products considers pheromones jointly with chemical pesticides. This situation generates difficulties for the registration procedure and increases their registration cost. Several proposals have been made by pheromone scientists, sponsored by the Ministry of Science and Technology, and by environmental agencies, research institutions and producers, to highlight the need to differentiate registration requirements for bio-pesticides, reduce their registration costs, considering the small size of the firms and their importance for the modernisation of Brazilian agriculture. The situation of Argentina is more complex since it lacks a national law of pesticides. There are several provincial legislations and national resolutions for the registration and evaluation of chemicals, and it is not uncommon that products forbidden in one province are allowed in others, and internationally banned pesticides are still available in the country. The National Program of Chemical Risk is currently working to comply with the international commitments signed by Argentina and to reinforce its capacity to manage the environment and preserve people's health. In Central America, IPM is the national strategy in Panama, Costa Rica, Honduras, Nicaragua, and El Salvador. Nevertheless, bio-pesticides are still considered as chemical pesticides in their system of registration. With support of GTZ, a group of scientists, politicians and producers are working towards a differentiated registration of botanicals and bio-pesticides for the region (Röttger and Carballo, 2004).

4. IPM research in Latin America

Research in IPM can be influenced by numerous factors such as legal and regulatory criteria, which may affect the expected returns of research, the availability of funds, the aims and objectives of local and external donor agencies, and the required scientific capacity to develop multidisciplinary studies. At this point, some general issues concerning scientific research in Latin America are described with some facts regarding IPM research and development in the region focused on semiochemical and microbial antagonists.

4.1. A brief outline of Latin American scientific research

Research and development have traditionally received comparatively little support in Latin American countries, where on the average less than 0.5% of GDP is devoted to R&D as compared to ca. 2.2% in developed countries (OECD, 2001). This is reflected in the lack of a critical mass of scientists—and hence decreased capacity to address multidisciplinary problems such as those derived from IPM (Bentley and Andrews, 1996), inadequate graduate training programs, and chronic shortage of funding for scientific research. Moreover, since most programs in the national granting systems are narrowly focused and oriented towards individual researchers, multidisciplinary research has decreased opportunities to receive funding. Furthermore, since scientists are judged mainly by their capacity to publish their results in high impact factor journals, research tends to be biased towards problems that are fashionable in developed countries where main journals are published and where most citations are produced, rather than towards locally relevant problems (Krauskopf, 2002). Most scientific research in Latin America is performed within the university system. Hence it suffers from distractions towards extensive teaching and outreach activities, an emphasis on basic rather than strategic or applied science, and also a certain degree of instability in research programs as they depend on short-term funding and the transient presence of students. Fortunately, most countries in Latin America have developed a system of agricultural institutes, to a large degree based on the USDA model, which perform agricultural research, although these institutes tend to be under-funded in relation to the problems they must face.

4.2. IPM research in Latin American

In general, IPM research and promotion have responded to two different strategies: food security and exports. The first one is concerned with the protection of a subsistence crop and is mainly focused on smallholder peasants, while the second one tries to fulfill the requirements of foreign markets and is concentrated in larger producers. Food security through crop protection is primarily funded by foreign donors and involves an important component of extension work for success. On the other hand, in many developing countries government programs and subsidies have been concentrated on medium and large commercial farmers, who are able to hire personnel to develop research, or to create links with external institutions.

Thus, in some countries, such as Chile, beside the national granting system, there are additional grant funds available for agricultural research and innovation projects involving partnerships with private firms under a commitment to transfer the results to potential users. In recent years, many of these projects have incorporated IPM practices, in part as a consequence of international trade treatries signed by the state. Given the requirements for partnerships, the program is not easily available for small farmers, and most research is guided by the specific needs of larger export companies. One example of this is a recent partnership between the Chilean government, a large forestry company and a local university to identify and synthesize pheromones of the pine moth, *Rhyacionia buoliana*, which is an important pest in Central and Southern Chile (FIA, 2003). Brazil provides another case of national IPM research that has not benefited local peasants. Brazilian researchers, producers and politicians agree that the country has achieved a significant level of scientific production regarding biological control and insect pheromones, based on the effort of government agencies, local universities and EMBRAPA. This is reflected in a great number of published articles and congress papers, but the scientific production does not respond to the real situation of the Brazilian agriculture since the results are not transferred to users (FEROBIO, 2002).

The previous examples refer to IPM research not directly involved in solving smallholder problems. In the first case, the grant system and the research is focused on benefiting large export farmers while in the second example, extensive research is done, but is not solution-oriented. Something different occurs in Central America, where, with foreign support, some regional institutions have developed IPM tools and peasants' participation methodologies that are extensively transferred to farmers by institutional consortiums and local NGOs (see Cobbe, 1998). This strategy initially responded to a need to provide food security, and later the research and efforts have turned to improve the capacity of peasant associations to participate in the global market. The production of organic crops for export seems attractive, so research, promotion and education projects mainly sponsored by foreign donors are directed to it. A different case is Cuba, where organic agriculture was adopted as part of its official agricultural policy. Government institutions and civil society organisations promoted it and established sophisticated research programs involving bio-fertilisers, bio-pesticides and the use of fermentation and tissue culture that laid the foundations for food self-sufficiency through organic management. Cuba seems to be a successful case of research, adoption and development of IPM and organic production, but this situation is not easily replicated in other countries. Besides the required agricultural policies, proper research and extension back-up efforts, Cuban organic producers do not compete with cheaper imported food, and farmers are not pressurised into using synthetic agricultural inputs.

5. Conclusions and recommendations

This paper reviewed some issues regarding IPM in Latin America. The importance of including peasants in the decision making process toward IPM adoption has been highlighted together with the complexity of the IPM paradigm. This was exemplified by the lack of adoption of economic thresholds both in developing and in developed countries. The provision of tools needed by peasants to solve their problems is crucial. The paper then reviewed two important economic issues regarding IPM: the size of the market for semiochemicals and microbial antagonists, and regulatory directives for registration of semiochemicals, specially focused on Latin American companies and regulations. The situation of IPM research in the region was described, with the need for collaboration between the entities involved stressed. The nature of collaboration will depend strongly on the type of farmer and crop it is geared around. For research aimed at pest control of subsistence crops, strategic alliances between local agricultural research institutions and universities should prove of value. This will draw the farmer and his needs into the research scheme thus applying the science to problems that need solutions. Hopefully it will provide access to local funds focused on basic science, and the local counterpart will be able to make a stronger case for imposing local priorities vis-à-vis those of foreign aid agencies and collaborating institutions. For research on cash crops of export value, farmers' associations should constitute important research partners, providing both expertise and funds to research programs.

Acknowledgements

This paper was presented at the workshop "Semiochemicals and microbial antagonists: their role in integrated pest management in Latin America" held at CATIE, Costa Rica, March 22–26, 2004. HMN thanks MISTRA/IFS for funding his participation. We are indebted to Profs. H.F. van Emden and S.D. Wratten for helpful comments on an earlier draft of the manuscript.

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